46TH EUROPEAN CONFERENCE ON VISUAL PERCEPTION

— 2024 —

25-29 AUGUST

ABERDEEN, SCOTLAND

Welcome Address

The 46th European Conference on Visual Perception (ECVP) took place in Aberdeen (Scotland), from August 25th to 29th, 2024. The conference saw the participation of over 800 fellow vision scientists coming from all around the world; the vast majority of them presenting their work, allowing us to offer an outstanding scientific program.

The conference featured 3 keynote lectures, 10 symposia, 17 talk sessions, 7 poster sessions, and 6 tutorials. Bevil Conway opened the conference with the Perception Lecture on Sunday, Tim Kietzmann gave the Spotlight in Vision Lecture on Wednesday, and Julie Harris the Rank Prize Lecture on Thursday. A rich social program included the Welcome Reception, the Illusion Night (with more than 35 exposition booths), the Conference Dinner, and finally, the Farewell Party. We also shared Scottish cultural experiences, from whisky tasting to a ceilidh.

This year, we also introduced Perceptio-Nite (a networking evening event targeted at students), and an exciting series of roundtable discussions at lunchtime to tackle some important debates in academia and scientific research in general. In addition, we introduced a new lecture format that we hope will catch on in the years to come — the Spotlight in Vision Keynote, in which an early or mid-career researcher talks about recent exciting findings in vision science. In this abstract book, you will find the summary of all contributions.

We hope that the ECVP 2024 in Aberdeen stays with you for a long time. We certainly will keep a fond memory of this meeting.

Mauro Manassi & Constanze Hesse
(on behalf of the organising committee)

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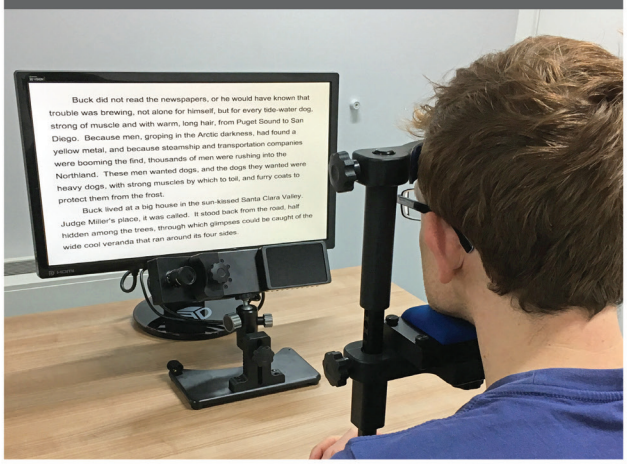

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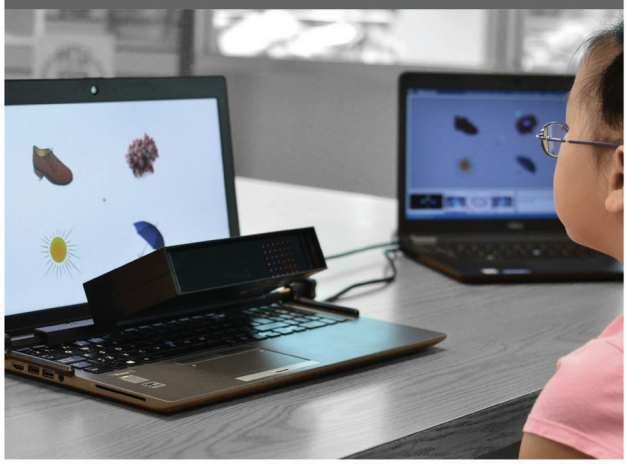

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Sunday 25th August

Perception Lecture

Principles of Neuroscience in Color

Dr Bevil Conway[1]
[1]National Eye Institute (US)
"What is color?" is among the oldest questions of psychology, prompting the earliest written records of philosophical theories of perception that date to Parmenides, Empedocles, Democritus, and Aristotle in ancient Greece. In this talk, I will take a tour of the evolutionary and cultural history of color, describing some surprising ways in which color has shaped the very practice of science and the development of western civilization, including modernism. I will attempt to integrate into this broad framework a discussion of neuroscientific experiments that use non-invasive brain imaging and psychophysics in humans and trichromatic monkeys, together with neurophysiological recording in monkeys, that aim to understand how spectral signals are transformed by the visual system into color. I will highlight work on color naming, the status of so-called unique hues, the origin of color concepts, memory colors, and the geometry of the neural representation of color. I'll endeavor to connect the lessons learned from the experiments to the more general pursuit of principles of neuroscience, with the ultimate goal of understanding what color is, and what color is for.

Monday 26th August

Poster Session 1

01

Material perception with GPT-Vision

Maarten Wijntjes[1], Yuguang Zhao[1]
[1]Delft University of Technology (NL)
Generative image models have been trained on text-image pairs and can thus take a textual input and generate a resembling picture. It is also possible to do the reverse, i.e. let a model generate text that resembles an input image. Recently, an extra functionality has been added to let one ask text questions about an image. This opens up possibilities to conduct psychophysical research on AI models, although in this case the psyche is artificial. To explore the possibilities, we let GPT-Vision participate in an experiment on material perception. We used an existing dataset that we recently generated on human observers in a material similarity experiment: we showed triplets of stimuli and asked the observer to pick the odd-one-out, or differently formulated: to choose the pair of stimuli that consist of the most similar materials. We gave GPT-Vision the same task and in addition asked to explain its' choice. We computed the coherence between human and artificial data and found that in 50% of the cases they gave the same answers (on 198 trails), where chance level is 33%. Although we did not have human data to compare to (humans only had to choose, without textual explanation), we were surprised by how perceptually literate the model performed. For example, it mentioned "metallic, reflective finish", "matte surface", "soft folds" "grain and texture visible", "appear more opaque", "transparent and glossy look" "gold-like appearance", etc. This indicates that the inability of machine vision to "see stuff" has largely been overcome.
Acknowledgements: This work is part of the research program Visual Communication of Material Properties with project number 276-54-001, which is financed by the Dutch Research Council (NWO).

02

Walking lends a helping hand to vision in the sound-induced double flash illusion

Cameron Phan[1], Alessia Tonelli[2], David Alais[1]
[1]The University of Sydney (AU), [2]Istituto Italiano di Tecnologia (IT)
Walking is an active movement regularly engaged in by most able-bodied individuals and studying human perceptual phenomena within this framework is pivotal to a more ecological understanding. Additionally, simultaneous travel in the spatial and temporal domains and the involvement of multiple senses make it a fitting context for phenomena related to the multisensory temporal domain. One such phenomenon is the sound-induced double flash illusion. Due to the advantage audition holds in temporal resolution over vision, an individual may perceive an additional illusory visual event (i.e., flash) when the auditory events (i.e., beeps) they experience outnumber their visual counterpart. On the one hand, the likelihood of experiencing these additional flashes increases as the time between the onset of events (stimulus onset asynchrony – SOA) decreases. On the other hand, the double flash illusion diminishes as the SOA exceeds the temporal binding window within which observers may bind two events together. In our study, we investigated the effect of walking on the double flash illusion by hypothesizing a reduction in the illusion during walking. We had individuals experience zero, one, or two flashes alongside zero, one, or two beeps whilst standing still, slowly walking, or walking at their normal pace. The SOA was 70, 100, 150, or 250 ms for conditions where two events occurred for either modality. Individuals' temporal binding windows were estimated for each condition using their responses. As expected, lower SOAs produced greater illusory experiences. Normal walking decreased the peak likelihood of experiencing the double flash illusion and, thus, reduced the amplitude of the temporal binding window. When individuals walk at a comfortable pace, they are less prone to experience visual illusion due to auditory input.
Acknowledgements: MSCA-2021-PF-01 g.a. No 101064748 - FLEX-U.

03

The role of colour in recognition of cultural landscapes

Galina Paramei[1], Yulia Griber[2]
[1]Liverpool Hope University (UK), [2]Smolensk State University (RU)
We explored the role of colour for memory of cultural landscape images. We hypothesised that the impact of colour on recognition of cultural landscapes would differ from that of natural scenes and vary with the degree of colour diagnosticity in cultural landscapes. Participants (N=154), aged 18–66 years (M = 24.9 +/- 9.3), had normal colour vision. Images (N=72), predominantly from the McGill Calibrated Colour Image Database, comprised three cultural landscape types: (1) artificially designed (parkscapes); (2) organically evolved (cultivated fields); and (3) associative (e.g. sacred sites). In the learning phase, 36 target images were presented randomly; the exposure varied as 64, 128, 300 or 2000 ms (block design). In the immediately following test phase, target images were interleaved with 36 distractors. Each target and distractor image were presented either in colour (C) or greyscale (G), with a Latin square design of the learning–test presentation combinations of targets and distractors. The recognition rate was assessed for the landscape type (3), colour mode (4: CC, CG, GC, GG) and exposure duration (4). We found colour advantage for image recognition in the CC mode: >90% for associative landscapes, and 60–70% for designed and organically evolved landscapes. When images were learned in colour and tested as greyscale (CG), the recognition rate was ca. 70% for associative landscapes, and >80% for designed and organically evolved landscapes. This hints that colour is more critical for recognition of cultural landscapes with low colour diagnosticity (associative). Unexpectedly, when cultural landscape images were memorised as greyscale and tested in colour (GC mode), their recognition accuracy was impaired (<50% for the two shortest durations). This finding is at odds with enhanced recognition of natural scenes rendered in (diagnostic) colour, reported earlier, and speaks against colour being a strongly bound attribute of memorial representation of cultural landscapes.
Acknowledgements: The project was supported by the Russian Science Foundation (grant No. 22-18-00407).

04

Visualization of Mental Templates in Human Sensory Information Processing Using Diffusion Model

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[1]Graduate School of Frontier Biosciences, Osaka University (JP), [2]MaiND Lab, Inc., [3]School of Engineering Science, Osaka University (JP), [4]Graduate School of Medicine, Osaka University (JP)
Understanding how mental models shape sensory judgments is both fascinating and challenging for cognitive science. Conventional psychological reverse correlation approaches have problems such as increased number of trials, low quality of the generated images, and significant dependence of the results on the base image, since the reverse correlation method is implemented using real space. To solve these problems, this study presents a new method that uses an image diffusion model. Inspired by the diffusion model, the method has two stages. First, the image is processed into perceptual latent space by an autoencoder fine-tuned for perceptual loss. Second, there is a second stage in which the diffusion model encoder projects this space deeper into a more general semantic latent space. By eliminating information irrelevant to the human cognitive representation, the similarity between the model-generated latent space and the latent space of the human brain is greatly enhanced. This strategic filtering ensures that our model sees only the most important features and patterns for social observation and cognitive evaluation, similar to the way humans process visual information. Furthermore, this two-step process not only improves the quality of the mental images we can reconstruct, but also allows us to trace real-world images into the model's latent space for deeper understanding of sensory judgments. Psychological experiments of evaluating attractiveness visual images with over 50 participants revealed that our model successfully captures and reconstructed mental image template for sensory judgments and that could predict the score of sensory judgment of new images with high accuracy. These results suggest that our model may serve as a model for computing semantic latent spatial distance and allow us to examine in detail the cognitive framework of sensory perception and stereotypy.

05

Functional dissociation between alpha and theta oscillations for feature-based and spatial attentional orienting and reorienting

Laurie Galas[1], Mehdi Senoussi[2], Niko Busch[3], Laura Dugué[1]
[1]Université Paris Cité, CNRS, Integrative Neuroscience and Cognition Center (FR), [2]Université Toulouse Jean Jaurès, CNRS (FR), [4]Institute of Psychology and Otto-Creutzfeldt-Center for Cognitive and Behavioral Neuroscience, University of Muenster (DE)
The processing of relevant visual information can be facilitated by covert attention. Attention can be voluntarily oriented and sustained at one location or explore spatial locations (spatial attention). Attention can also be sustained on a stimulus feature or explore the feature space (feature-based attention). Previous results associated sustained spatial attention with alpha (8-12Hz) and exploratory attention with theta (4-7Hz) brain rhythms. However, evidence regarding the nature of attentional exploration across the stimulus space (for a location or a feature) and its neural substrate remains limited. We used a voluntary attention cueing paradigm while human participants' brain activity was recorded with electroencephalography. Sustained and exploratory attention across both location and feature space were manipulated independently. A classifier trained and tested on the attended dimension (a location or feature) assessed the neural representation dynamics of attentional orienting (cue-to-target period). Generalized across time, classification accuracies revealed oscillatory patterns at alpha and theta frequencies for feature-based attention (attention sustained on a feature but exploring space as the target location is unknown) and alpha for spatial attention (spatially sustained but exploring the feature space). We further analyzed theta oscillations in the post-target period and found stronger theta power in invalid trials (when attention was on the distractor location or feature and needed to reorient to the target) compared to valid trials with a stronger effect for spatial attention compared to feature-based attention. We interpret the stronger effect in the spatial attention condition as a result of spatial exploration being already engaged in feature-based attention before stimulus onset. Additionally, we found a correlation between behavior and brain activity with faster reaction times linked to stronger theta power. Together, our results suggest that alpha oscillations are associated with sustained attentional orienting regardless of the attended dimension, and theta oscillations are related exclusively to spatial attentional exploration.

Acknowledgements: This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 852139 - Laura Dugué) and the Agence Nationale de la Recherche (ANR)-Deutsche Forschungsgemeinschaft (DFG) programme (grant agreement No. J18P08ANR00 - Laura Dugué).

06

A Stroop effect for material appearance

Hua-Chun Sun[1], Jacob Cheeseman[1], Giacomo Aldegheri[1], Roland Fleming[1], Filipp Schmidt[1]
[1]Justus Liebig University Giessen (DE)

Both perceptual and semantic aspects of materials provide rich information about stuff around us. For example, objects with shiny surfaces are likely to be hard and heavy, and most metallic materials share similar characteristics. Yet, how the representations of material words and their visual attributes are processed and integrated in the brain is still an open question. Here we exploited the Stroop paradigm to uncover interactions between visual and semantic encoding of material categories. We presented the names of 11 materials in different fonts with specific material appearances, e.g. the word "metal" rendered in metallic font (congruent condition) or in wooden font (incongruent condition). Each stimulus was shown for two seconds. In half of the blocks, participants (n=51) read the written words, in the other half they reported the font material of the letters, (no time limit was specified). Half of the material naming and word naming blocks featured grayscale stimuli to estimate the role of color. In total, each participant completed 484 trials of German language speech responses, i.e. 11 material words x 11 material fonts x 2 naming blocks (word naming or material naming) x 2 (color-scale or grayscale blocks). Onset times were measured using different speech analysis methods. We found that participants took significantly longer to name material fonts than material words, and the response in congruent conditions was slightly faster than in incongruent conditions. Our results suggest that the visual properties of materials are extracted automatically, facilitating the processing of semantically congruent information.

Acknowledgements: DFG (222641018 – SFB/TRR 135 TP C1), the HMWK ("The Adaptive Mind") and European Research Council Grant ERC-2022-AdG "STUFF" (project number 101098225).

07

Binocular rivalry dynamics are abnormal in amblyopia

Adrien Chopin[1], Aubrey Rossi[2], Preeti Verghese[1], Michael A. Silver[4], Dennis M. Levi[3]
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Binocular rivalry is a phenomenon where human perception alternates between two disparate images presented continuously to each eye. Previous studies have predominantly focused on rivalry in people with non-amblyopic strabismus, used brief stimulus presentations, or solely reported overall rivalry dominance. In this study, we investigated the dynamics of sustained rivalry by presenting orthogonally-oriented gratings one in each eye of 11 amblyopic patients (6 anisometropic, 1 strabismic, 4 mixed) and 7 control participants. Participants reported their percepts during 1-minute presentations. Interocular contrast and alignment were individually adjusted to avoid diplopia. Amblyopic patients experienced fewer reversals (alternation between two different exclusive perceptual states, e.g., a sequence of left, mixed, then right percepts; $p = 0.0002$) and higher proportions of incomplete reversals (e.g., a sequence of left, mixed, then left percepts; $p = 0.02$) compared to controls. Patients with anisometropic amblyopia experienced more incomplete reversals than patients with strabismic or mixed amblyopia ($p = 0.03$), suggesting larger binocular noise levels in anisometropic amblyopia. Patients spent less time perceiving the weaker eye stimulus than control subjects ($p = 0.005$) but similar time perceiving mixed percepts ($p = 0.35$) or the dominant eye stimulus ($p = 0.97$). The reversal rates were sufficient to distinguish amblyopic and control observers, except for one participant. Adding the proportion of time spent seeing the dominant eye stimulus while experiencing exclusive percepts allowed complete differentiation of patients with anisometropic amblyopia from those with strabismic or mixed amblyopia. Further, by adding the proportions of incomplete reversals, control participants could be entirely separated from patients with anisometropic amblyopia and from patients with strabismic or mixed amblyopia. We conclude that amblyopic patients experience binocular rivalry with severely abnormal dynamics, making it a promising candidate for a diagnostic tool.

Acknowledgements: This research was supported by the European Commission Marie-Curie award PIOF-GA-2012-327905 (AC), a Smith-Kettlewell postdoctoral fellowship (AC), NEI grants RO1EY020976 (DML) and R21EY030609 (DML), and NEI Core Grant P30 EY003176 (MAS and DML).

08

An open-source vision-science tool for the auto-regressive generation of dynamic stochastic textures Motion Clouds

Nikos Gekas[1], Andrew Isaac Meso[2], Jonathan Vacher[3], Laurent Perrinet[4], Pascal Mamassian[5], Guillaume Masson[4]
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Motion Clouds are a generative model for naturalistic visual stimulation that offer full parametric control and more naturalism than the widely used alternatives of Random Dot Kinematograms (RDKs) or luminance gratings. We previously released an 3D FFT-based generation algorithm (Sanz-Leon et al., J Neurophysiol, 2012). Here, we present a novel implementation of motion clouds that uses an Auto-Regressive formulation so that any number of frames can be generated quickly with parameters changed in near real time, as needed in closed loop experiments. We demonstrate a version of the proposed toolbox that will be available online to illustrate the level of control available. With a graphic user interface, researchers can use interactive sliders to adjust motion cloud parameters like central frequency, orientations and bandwidths to get an intuitive feel for the parametric changes. We provide functions that can be easily integrated with psychophysics task tools like Psychtoolbox. Motion clouds can be used to generate trials of stand-alone moving

luminance textures or added to other stimuli like images or videos as dynamic noise to disrupt visual processing. The toolbox can be run using GPUs to speed up generation to pseudo real-time for large stimulus arrays of about 1024 by 1024 pixels at 100Hz. We argue that this tool can enhance visual perception experiments in a range of contexts and would like it to be open to extensive testing, use and further development by the psychophysics, computational modelling, functional imaging and neurophysiology communities.

09

The face-name matching effect in a Serbian context

Sunčica Zdravković
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It has been shown that people can perform at above chance levels when asked to select the correct first name of an unfamiliar person depicted in a photograph when that name is offered in a small list of alternatives (Zwebner et al, 2017). This face-name matching effect seems to be culturally driven, as participants are only successful when the depicted names and photographed faces are from their own culture (their language and ethnic group). We replicated the described effect in Serbia, using photographs of local people with Serbian names. The accompanying filler names were chosen to have the same frequencies of occurrence in the population as a particular correct name. We obtained an even higher percentage of correct answers (31%) than in the original study (28%), even though our stimuli control was somewhat stricter. In a second experiment, personal names were replaced with family names, and again a significant effect was obtained, although the absolute percentage of correct answers was lower (27%). Given that the face-name matching effect is a form of self-fulfilling prophecy, it might appear to be cognitive in nature. However, it is driven by low-level features of the visual stimuli, consequently, a trained artificial neural network can achieve the same success rate as humans (Zwebner et al, 2017). We tested this finding by running participants who have mild or more severe deficits in face recognition. They struggle with the identities of famous people shown in photographs but can often recognize familiar faces based on internal and external facial features. Hence, they are a good match for a machine-learning algorithm that associates visual stimuli with tags (i.e., faces with names). The obtained pattern of results for this group of participants will be discussed in comparison to the previously tested typical Serbian population and findings from the artificial network.

10

ERG correlates of the famous ramp aftereffect

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Purpose: After presenting a visual adaptation stimulus with sawtooth-modulated repetition of increasing/decreasing luminance, a subsequent test stimulus with constant luminance is perceived as dimming/brightening. This was first described by Anstis (1967) as the ramp aftereffect. So far, its anatomical location and the underlying mechanisms are unknown. This study aimed to identify relevant steps along the retinal processing chain using electroretinography (ERG). Methods: As adaptation stimuli full-field luminance was modulated in time following a sawtooth pattern (upward or downward ramps at 2 Hz). The test stimulus, probing the adapted state, was a subsequent 100 ms sequence of flash lights. A third control condition used a constant luminance adaptation stimulus. We analyzed the following ERG components evoked by the test stimulus: low-frequency awave, bwave, onPhNR, dwave and offPhNR, and high frequency oscillations. Subjective perception was recorded in a complementary psychophysical nulling experiment using the same stimuli. Results: Psychophysics. We replicated the ramp aftereffect with upward/downward luminance ramps eliciting a dimming/brightening aftereffect. Consistent with previous findings the effect was stronger with upward adaptation. ERG. We found significant differences in all ERG components between the control condition and the ramp adaptation. Moreover, we found stronger changes in activity after downward adaptation to the upward adaptation. No correlation between psychophysical results and ERG components was found. Conclusion: Given the opposing nature of our adaptation ramp conditions (upward versus downward) we expected opposing effects in the ERG but only found differences in strength. Moreover, we expected differences between the upward and downward ramp conditions for specific ERG components (i.e., retinal processing steps), but instead found differences in the whole retinal processing chain. This prompts for consideration of post-retinal stimulus processing as a potential locus of direction-specific ramp adaptation.

11

Pre-saccadic Attention (and not arousal) modulates the Size-Eccentricity Effect

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Peripherally located objects are often perceived as smaller than centrally located objects, a perceptual phenomenon known as the size-eccentricity effect. This phenomenon, mainly due to the structural properties of the visual system, is further modulated by covert attention (i.e., attention directed to a specific location without eye movement). In this study, we investigated whether pre-saccadic attention (attentional resources closely linked to ocular saccades) could also compensate for this effect. Participants (N=16) performed a judgment task where they had to compare a test disk of varying size, briefly presented in peripheral vision, to a reference disk appearing about 450 ms later in foveal vision. Psychometric function parameters were computed. When no saccade was made toward the location of the test disk, the size-eccentricity effect was observed. However, when participants initiated saccades about 200 ms after the extinction of the test disk, points of subjective equality were close to objective equality. Discrimination sensitivities remained unaffected, indicating similar task difficulty levels. These results were replicated in a second experiment (N=16), which also aimed at ruling out an alternative explanation involving non-specific arousal mechanisms, also known to enhance visual perception. Participants executed either a non-oriented finger movement (keypress) or an antisaccade instead of a saccade. The size-eccentricity effect disappeared only in the saccade condition, confirming that the size-eccentricity compensation associated with saccades is due to a shift of pre-saccadic

attention rather than arousal. Therefore, pre-saccadic attention not only improves the processing of orientation, contrast and spatial frequency (as previously demonstrated), but also improves the processing of peripheral object size. Presumably, the shift of receptive fields observed towards the focus of covert attention, likely responsible for the modulation of peripheral object size perception, is potentiated by pre-saccadic attention.
Acknowledgements: This work was supported by the ANR-18-CE28-0001 (CP).

12

Perceptual learning improves motion perception in patients with age-related macular degeneration

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Maculopathies such as age-related macular degeneration or Stargardt's disease are typically characterized by a progressive and irreversible loss of central vision which has a dramatic impact on the patients' quality of life. A promising readaptation strategy for patients is to train their peripheral vision, which remains functional, in order to diminish their visual impairments. Here, we explore whether perceptual learning can improve patients' ability to perceive motion that relies on both central and peripheral vision. Nine participants with either age-related macular degeneration or Stargardt's disease (absolute scotoma in both eyes, aged between 50 and 81) performed 12 training sessions of about an hour and spread over 4 weeks. During each of these sessions, they had to report the motion direction (either upward or downward) of a translating pattern defined from dynamic random-dot kinematograms. All participants improved their performances with the training (mean improvement rate [(post-test result - pre-test result)/pre-test result]*100): 38.3 percent +/- 8.3 percent of standard error; p=0.0078, Wilcoxon test), which suggests that perceptual learning is efficient in this case. In order to determine whether these effects can be generalized to untrained and more complex motion tasks, we investigated the performances of 5 of the patients on a multiple object tracking task, before and after the training. Analyses showed that tracking performances were also generally improved after the training (mean improvement rate: 7.4 percent +/- 4.5 percent of standard error). These results suggest that perceptual learning is an effective tool to improve motion perception in patients with maculopathies and that the effects of training on a simple motion discrimination task might transfer to more complex tasks. Overall, these results open interesting perspectives for the development of effective readaptation strategies based on perceptual learning in maculopathy patients.
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Gaze-centred hypometric pointing in Peripheral Vision Modulated by Covert Attention

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The SPL-IPL lesion causes optic ataxia (OA) characterized by gaze-centred hypometric pointing to targets in the affected peripheral visual field. The SPL-IPS is also involved in covert attention. We aimed at investigating the possible link between attention and action, and whether the attentional deficit could cause the gaze-centred hypometria in OA. Modulation of action by attention was evaluated as the effect of valid or invalid cue on pointing performance in healthy subjects and OA patients. Invalid trials involved a totally random presentation of the visual target, in terms of eccentricity (15, 20, 25, 30 or 35°) and visual field (left or right), as in the usual assessment of peripheral reaching performance in OA, whereas valid trials involved presentation of a visual target in the cued field at the same blocked eccentricity. The first experiment displayed a central cue (arrow) with 75% of side-validity, while the second experiment used a peripheral cue of 50% of side-validity. Diverting attention to the opposite visual field (invalid trials) in experiment 1 allowed to mimic the pointing pattern of OA patients in healthy controls. The second main finding of experiment 1 was that pointing performance in patients with OA could be improved with valid side and positional cueing. In contrast, experiment 2 did not show any consistent effect of peripheral cueing on pointing performance, neither in healthy controls nor in patients with OA. These results suggest that the visual field effect of AO may result from an impaired ability to orient covert endogenous attention toward the affected visual field. The improvement would then be explained by the use of residual resources of endogenous attentional shifting with possible anticipation and amelioration of accuracy. In contrast, the exogenous attention capacities, preserved in patients, do not seem to be able to compensate for their deficit.

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Does human perception have access to purely monocular information?

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Recent neurophysiological findings challenge the traditional belief that there are purely monocular cortical cells in early visual cortex V1, suggesting that cells previously classified as monocular may encode information from both eyes through facilitatory or inhibitory modulation. Our recent psychophysical work supports the idea that the human visual system is inherently binocular, even in the case where one eye is occluded. However, other computational modeling efforts rely on the assumption that monocular channels can support human perception. Our goal was to address the question of whether there is evidence for a purely monocular channel in human vision. We hypothesized that if there is a purely monocular visual channel, it would be able to provide some independence from the effects of noise in the fellow eye in a dichoptic noise masking paradigm. We employed a dichoptic noise masking detection task. In a two-interval-forced choice (2IFC) paradigm, the subject's task was to detect the presence of a Gabor patch target in the presence of an overlaid dichoptically presented noise patch (bandpass 1/f noise) of increasing contrast. Stimuli were displayed on a passive 3D screen. 10 levels of noise mask contrast, ranging from 10% to 100% were tested. We observed that the detection threshold in one eye monotonously

increases as a function of the mask's contrast in the other eye without showing any region of signal/noise independence, suggesting the absence of a purely monocular channel subserving contrast detection.
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Testing Limits of Ensemble Perception

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Visual scenes are too complex to immediately perceive all their details. As suggested by Gestalt psychologists, grouping similar scene elements expedites evaluating scene gist. Ensemble perception efficiently represents similar objects, overcoming processing, attention and memory limits. Observers are better at perceiving image set means than remembering presence of set members. Ensemble perception occurs explicitly, when observers judge set mean, and automatically, implicitly, on-the-fly, trial-by trial, when engaged in an orthogonal task. We are studying ensemble perception phenomena, testing limits of temporal integration. We present 10 circle or line images in RSVP (rapid serial visual presentation) sequence with variable SOA (stimulus onset asynchrony), followed by a 2-AFC (2-alternative forced choice) test (seen vs. new images) measuring memory of their size or orientation, determining speed (for brief SOA) and period (for long SOA) of efficient integration forming a mean. Another series of experiments used the classic Deese–Roediger–McDermott (DRM) paradigm. We present 8 images in RSVP sequence, with or without their central prototype, followed by a screen of 8 images, some seen, some new, including a prototype; participants mouse-clicked images they judged were present in the sequence. In both experiments, participants tended to choose test images closer to the mean or prototype. In the first experiment, this tendency was gradually reduced for very long SOA. In the second, the tendency was reduced for later clicks. We conclude that, while found for a broad spectrum of stimuli and presentation modes, ensemble perception still has its limits.
Acknowledgements: Israel Science Foundation (ISF).

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Testing the Proportional Rate Control: Drivers use Different Proportional Rate Values when Braking Capability Changes

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Proportional rate control for visually guided braking offers a range of proportional rate (PR) values that, when held constant, could result in successful braking. Choosing a different PR value within this range only affects the timing of the approach. This flexibility makes proportional rate control more robust to perturbations that constrain and/or change our action capabilities. When the braking capability changes (as in the case of when driving from a paved road onto an unpaved road), a driver can still achieve soft contact with a target by using a different PR value. The present study tested the proportional rate control by manipulating the strength of the brake. Participants were presented computer-generated displays simulating an approach along a linear path to a target and were asked to stop as close as possible to the target by using a foot pedal as brake. The maximum deceleration allowed in the strong, medium, and weak brake conditions were 4.8 units/s², 3.6 units/s² ve 2.4 units/s², respectively. The main effect of the brake strength on the mean PR values during approach was found to be significant, $F(2, 54) = 8.027$, $p < 0.001$, $\eta^2 = 0.229$. Bonferroni adjusted pairwise comparisons revealed that the mean PR values in the strong brake condition (–5.28, SD = 1.68) were significantly higher than those in the medium (–6.63, SD = 1.43) and the weak (–7.12, SD = 1.34) brake conditions. The mean PR values in the medium brake conditions were not significantly different from those in the week brake condition. The results indicate that when braking capability changes, people use different PR values to stop successfully at the target, providing evidence for the flexibility of the proportional rate control.
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Reliability of static visual field assessments in children with cerebral visual impairment (CVI)

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Purpose: Visual field (VF) assessment is a key diagnostic tool in cerebral visual impairment (CVI). Performing a VF test in children with CVI is difficult, related to, e.g., test duration. Glaucoma tendency oriented program (GTOP) can be used for a quick VF assessment in CVI children. Determining if a GTOP test result is reliable is difficult, as the standard reliability indices as used in adults (false positive and negative responses) seem to flag too many VFs as unreliable in children with CVI. Aim of the study was to assess the reliability of GTOP in children with CVI using alternative reliability criteria. Methods: 45 children with CVI, median (IQR) calendar age 11 (9-14) years, 39% girls, underwent a VF test with GTOP in Octopus 900. Reliability for GTOP requires false positive and false negative responses each not exceeding 25%. We used the following alternative reliability criteria: i) blind spot correctly detected, ii) no trigger-happy or fatigue defect curve pattern, iii) no rim or lid artifact, iv) duration < 5 minutes, v) defects in corrected probability plot not exceeding defects in probability plot, and vi) no examiner's remark indicating poor performance. A score of 1 (yes) or 0 (no) was given for each criterion, resulting in a score between 0 and 6. Results: We analyzed 87 eyes of 45 children. Median test duration was 3.1 (2.4-3.3) minutes. Percentages of false positive and negative responses were 33 (0-67)% and 0 (0-25)%, respectively; 64% of the VFs were formally unreliable. Median score of the alternative reliability criteria was 6; only 17% scored below 5. Conclusion: Children with CVI have a high number of false positive responses, possibly related to low developmental level and a lack of inhibitory control. Our alternative reliability assessment suggests that many of these apparently unreliable VFs may contain useful information.
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Eye movements evoked by binaural monopolar galvanic vestibular stimulation

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Galvanic vestibular stimulation (GVS), artificially activating the vestibular system, is increasingly used in perception and neuroimaging research. Even if its mode of action is more and more understood, some features remain unknown, and since the vestibular apparatus is highly linked to the oculomotor function, eye tracking could be a valuable tool for mastering GVS. Eye response to galvanic vestibular stimulation in its usual configuration, that is bilateral bipolar, consists of a torsion in the direction of the anode, plus a "skew eye deviation" and a weak horizontal movement towards the anode. The direction of this response is similar to that of the postural response and is compatible with GVS inducing an apparent dynamic roll-tilt of the head towards the cathode. In the present study we investigated binocular eye movements induced by another GVS configuration: binaural monopolar. In that case, the vestibular stimulation triggers a body response in the anteroposterior plane and activates a specific cortical network. We hypothesize that binaural monopolar GVS induces either vertical or vergence eye movements, or both, consistent with the mimicking of a pitch-tilt. Subjects with normal or corrected to normal vision were included in the study. GVS was delivered from 2 stimulators through disposable electrodes stuck over the mastoid and C7 cervical bone. Two-s pulses were delivered at three GVS intensities: 0.4, 0.6 and 0.8 mA, randomly distributed. Binocular eye movements were recorded using a video-based eye-tracker sampling at 1000 Hz. The possible influence of a fixation cross was also assessed. Qualifying and quantifying the ocular response to anteroposterior GVS will first allow us to infer the neuronal network involved and also offer perspectives of using the GVS-evoked eye deviation as an easy to get and precise biomarker of vestibular function.
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Material and weight influence perceived value of novel objects in visuo-haptic interactions

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Perception does not only include discriminative, but also affective and evaluative processes, which then can inform decision-making. A number of marketing-oriented studies showed that weight and packaging material of specific products, such as wine, coffee or a torch, affect the assumed utility or acceptable price for that product. Here, we asked from a theory-driven perspective how these properties would affect perceived value of objects in general, independent of specific products. For that purpose we created 27 novel, unfamiliar objects, that varied in material (metal, wood, plastic), shape (triangle, square, hexagon) and relative weight (light, normal, heavy). Objects had a diagonal of around 100 mm, were 20 mm high and had a circular hole of ~30 mm diameter in their middle. Normal-weight objects were solidly made out of the visible material; light and heavy objects were manipulated to be ~45 % lighter or heavier than the solid ones while still having the same centre of gravity. Participants lifted each object once, and judged it on visual analogue scales according to different adjectives covering a representative set of evaluative, affective and sensory ratings—while holding the object in their hands. Using confirmatory factor analysis, we constructed a score for perceived value, based on equally weighted ratings from 4 adjectives ("wertig", "hochwertig", "minderwertig", "authentisch"). This value score was strongly influenced by the material, modified by the relative weight—but not by shape. Metal and wood objects were perceived as of higher value than plastic objects. The perceived value was the higher the higher the relative weight–in particular for metal, and less so for plastic. Overall, our results suggest that the interaction between visually accessible material and haptically perceived weight shapes perceived value independent from a specific product.
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Biased localization and interception – shared mechanisms underlying representational momentum and tau effect

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When we observe a moving object, our perception and judgements of specific positions of that object are subject to biases. A frequent finding is that the final visible location of that object is perceptually shifted in motion direction – called the 'representational momentum'. Another spatial bias is called the 'tau effect'. It shows that we misjudge spatial distances based on temporal features, for instance, the time gap between the presentation of two objects whose spatial distance is judged. Importantly, both effects have been explained by the same underlying mechanism, namely a speed prior impacting our motion prediction. If the same underlying factor causes both effects, participants who show a larger representational momentum should also be more biased in the tau effect. We aimed to experimentally test this proposed association by comparing these spatial biases in the same sample. In both tasks, we presented a black dot on a touchscreen. The dot 'moved' intermittently across five locations from left to right or right to left. Participants either had to localize the remembered final position (representational momentum) or intercept the predicted fifth location after four presentations (tau). We tested over 60 participants in both tasks and correlated i) their general tendency to overshoot and ii) the impact of temporal manipulations on their bias. We found two moderate correlations, showing that the two biases i) are related across participants and ii) are similarly impacted by temporal manipulations. These results indicate a shared mechanism that might drive both the representational momentum, as well as the tau effect. Future studies might reveal whether additional biases can be explained by a shared factor and whether a (slow) speed prior can account for these effects.
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Analysis of gaze patterns when using progressive lenses during visual acuity measurements at different distances

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The statistics of saccades and fixations are indicators of the efficiency of a visual task such as reading: shorter fixation and saccade time, smaller number of fixations, and smaller total saccade amplitude indicate a more efficient reading pattern. Characterizing these eye movements during a reading task while using different Progressive Power Lens (PPL) designs would improve the understanding of the eye-lens system and consequently aid in refining the designs. In this study we analyze different eye movement parameters when subjects perform a VA test utilizing eye-tracking technology. The study involved 27 participants on a prospective observational double-masked study. They undertook both near and distance VA tests using three pairs of Free-Form lenses: Endless Steady Balance, Endless Steady Near and Endless Steady Distance (IOT,S.L.). Participants were asked to read Sloan optotypes at 37 cm and 5.25 m, arranged in isolated lines of 6 letter each. The pupil position was recorded with an eye-tracker (ET; Tobii Pro Glasses 3, Sweden). The eye movements analyzed were Fixation time, Saccade time, Number of fixations, and Saccade amplitude. The findings revealed that participants spent less time on fixations (p-value<0.05), also on saccades (p-value<0.05), required fewer fixations (p-value<0.05), and made shorter saccades (p-value<0.05) when using the distance-specialized PPL design (Endless Steady Distance) during the distance VA test. Similarly, in the near VA test, employing the near-specialized PPL design (Endless Steady Near) yielded comparable results with less time spent on fixations (p-value<0.05), on saccades (p-value<0.05), fewer fixations (p-value<0.05), and shorter saccade distances (p-value<0.05). The results of this study show that a distance-specialized design provides a more efficient gaze pattern at distance whereas the near-specialized design improves efficiency for near vision. In conclusion, the analysis of fixation and saccadic characteristics correlate with the PPL power distribution, and therefore can be a guide for more efficiently design progressive lenses.

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Boosting transfer in perceptual learning using transcranial random noise stimulation

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Perceptual learning is the process by which performance in a perceptual task is enhanced through repeated practice, leading to long-term improvements that are likely to originate from neuroplasticity in the cortical sensory areas that support the trained function. Transcranial random noise stimulation (tRNS) is a non-invasive brain stimulation technique that has emerged as a potential enhancer of sensory processing through the increase of cortical excitability and neuroplasticity. This protocol employs fluctuating currents randomly spanning a broad range of frequencies and amplitudes. The mechanism underlying the effects of tRNS on vision potentially involves stochastic resonance, a phenomenon whereby the random noise introduced in cortical visual areas can boost their signal processing capabilities. This enhancement in sensory processing could in turn facilitate improvements in visual tasks that gain from training. As orientation represents a basic visual attribute to which the early visual system is particularly sensitive, orientation discrimination tasks have been employed in classic paradigms to shed light on the properties and dynamics of perceptual learning. We used an orientation discrimination task to assess whether performance benefits achieved through training could occur more rapidly with tRNS compared to sham stimulation. Additionally, we investigated if such benefits could transfer to retinotopic locations and orientations beyond those explicitly trained. Participants with normal or corrected-to-normal vision were randomly assigned to receive either tRNS or sham stimulation across multiple training sessions. The ten-day study protocol included a baseline assessment on the first day, followed by eight days of training on a single combination of locations and orientation, and a final test session on the last day. The variability observed in individual results provides insights into the mechanisms of perceptual learning and their implications for the application of tRNS in interventions aimed at rehabilitating low-level visual functions in patients.

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Individual differences in colour vision and their impact on perceived characteristics of food

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Colour appearance of food conveys information about material properties that may guide food-related behaviour, yet individual factors including colour vision characteristics may influence this relationship. For example, the greenness of a banana may signal unripeness and therefore inedibility to some, but not to others with lower sensitivity to colour differences. In a previous study involving participants with confirmed normal colour vision (NCV), we found significant correlations between colour appearance and perceived sweetness, freshness, nutritive value and appetisingness for artificial fruits presented under changing near-metameric illumination. Here, we examine whether similar associations occur for participants with colour vision deficiencies (CVDs). The experiment was conducted in a white-walled lightroom illuminated solely by spectrally tuneable lamps. Following 60-seconds adaptation to a neutral-chromaticity reference illumination (~D65), participants (N = 28, aged 18-26 years; NCV: 8 males; CVD: 10 males; 4 dichromats, 6 anomalous trichromats) viewed different instances of four real fruits (banana, orange, red apple, pear) across successive 60-second trials, interspersed with 10-second dark intervals. On each trial, a single fruit appeared under one of its three selected illuminations (all near-metameric to D65), each generating a distinct fruit colour appearance against a constant background. Participants viewed the fruit freely, while rating nine characteristics (appetisingness, flavour intensity, sweetness, ripeness, freshness, nutritive value, naturalness, juiciness and firmness) on a Likert scale. Subsequently, participants completed a behavioural habits questionnaire and underwent comprehensive colour vision testing, including anomaloscopic examination. Preliminary findings for banana and pear reveal that participants with NCV and CVD show similar trends for the effect of changing hue on all characteristics, apart from ripeness. Notably, hue significantly affects perceived

nutritive value and naturalness for banana, and appetisingness for pear in both NCV and CVD groups. Investigation continues into the influence of specific colour vision phenotypes on the relationship between colour appearance and perceived fruit characteristics.

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Unseen yet recognized: unconscious processing of upright and inverted Mooney faces

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Previous studies have indicated that upright faces and specific objects receive preferential processing even without conscious awareness. This study extends these findings by exploring the perceptual prioritization of ambiguous stimuli, specifically utilizing “Mooney faces.” Our experimental setup involved the use of continuous flash suppression (CFS), a psychological technique that masks visual stimuli with rapidly changing masks. We presented both upright and 180° rotated Mooney faces to participants who were unaware of the stimulus presentation. The experiment was conducted with 22 participants using a Varjo Aero head-mounted display, which flashed dynamic masking stimuli at 10 Hz while recording gaze data for subsequent analysis. The experimental protocol required participants to (a) localize the stimulus (4 quadrants), (b) determine its orientation (upright or inverted), and (c) report perceptual awareness (not visible, brief, partially, completely visible). Our analysis focused exclusively on trials where participants responded, “not visible.” A one-sample t-test for each orientation condition revealed that, despite the complete suppression of the Mooney faces, participants could localize upright stimuli significantly above chance levels; however, detecting inverted stimuli did not reach statistical significance, suggesting a preference for processing upright stimuli. Moreover, the calculated saccadic index—representing the differential proportion of saccades directed towards the target—remained significantly positive for both stimulus conditions, indicating a consistent saccadic preference toward the stimulus location regardless of conscious perception. In summary, our findings demonstrate a significant, consistently positive saccadic index and accurate localization of upright stimuli. This suggests an advanced processing mechanism beyond simple visual processing that enables our unconscious system to detect upright ambiguous stimuli.
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Comparing Shape Distortion in Frame Effect and Flash Grab Effect

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Objects can often appear at a different location than they actually are when they are in the vicinity of motion (such as in flash grab effect) or inside another moving object (such as in frame effect). Recent research has shown that motion not only shifts the perceived position of nearby flashed objects but also distorts their perceived shape. A recent study demonstrated that a flash grab stimulus, known for inducing significant position shifts, also caused substantial distortions of canonical object shapes. Here we ask whether the frame effect, which can induce position shifts up to three times larger than the flash grab effect, similarly distorts object shapes. To investigate this hypothesis, we conducted experiments where participants adjusted the vertical component of a "T" shape object until it appeared symmetric. The "T" shape was flashed onto one of five stimuli that spanned a continuum from a flash grab stimulus to a frame effect stimulus. These started with a rotating annulus which across the other four conditions unfolded into a translating frame. Our findings revealed that the amount of shape distortion induced by the frame effect was approximately half that of the flash grab effect. Besides the dissociable speed profiles of these two effects, this result highlights yet another distinction between the flash grab effect and the frame effect, suggesting separate underlying mechanisms.

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Feedback of self-action enhances visual time estimation when performed together.

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In everyday life, visual time estimation is an essential ability to predict the future position of moving objects temporarily hidden from view. Studies suggested that visual time estimation is biased during the execution of motor action, but others suggested that it can be facilitated. Additionally, visual feedback of motor action improves precision and control, enabling continual error correction between the response and the action. This research investigated how visual feedback of motor action can alter visual time estimation using a prediction motion task. To this end, 34 participants had to judge whether an occluded object had reappeared earlier or later than expected in two different conditions: a visual condition (VIS) and a visual condition with motor action (VISMOV). Motor action consisted of tracking object motion through an elbow extension. Participants were separated into two different groups depending on whether they received visual feedback (FB) or no feedback (No-FB) on the motor action during the VISMOV condition. An ANOVA Group (FB, No-FB) x Condition (VIS, VISMOV) was performed on the accuracy and precision of the psychometric curves separately for each condition and each participant. We demonstrate that adding a motor action with associated visual feedback in VISMOV condition can improve our temporal judgment abilities, specifically by improving participant precision ($F(1, 28) = 6.752$, $p = 0.015$, $\eta^2p = 0.195$). Unexpectedly, motor action without visual feedback had no discernible effects on participant judgment, neither on accuracy ($t(13) = -1.460$, $p = 0.168$) nor on precision ($t(13) = -0.051$, $p = 0.960$). In order to understand the results in detail, we aim to examine the effect of subject tracking performance within the feedback condition. Specifically, this involves comparing the difference between the position of their arm/feedback to the target's position on the screen in relation to temporal judgment performance.

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Exploring Image Aesthetics with Machine Learning: Insights from Explainable AI

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We present a diverse set of machine learning (ML) models for aesthetics research, alongside the introduction of explainable AI (XAI). Our models include Random Forest, XGBoost, Support Vector Regression (SVR), and Multilayer Perceptron, providing the first comparative analysis of various ML models in computational aesthetics. These models leverage aesthetic attributes to predict the aesthetic scores of images. Additionally, for the first time in this field, we apply the popular XAI technique SHapley Additive exPlanations (SHAP) to enhance model interpretability. SHAP clarifies the importance of features by assigning 'SHAP values', which are derived from game theory, indicating their contributions to the model predictions. We implement our methodology on the Aesthetics with Attributes Database (AADB), providing insights into the roles of attributes and their interactions. Our results show that all ML models perform well on the AADB dataset, with SVR slightly outperforming the rest. Applying SHAP analysis to the SVR model revealed that the 'content' attribute is the most influential feature in predicting overall aesthetic scores, followed closely by 'object emphasis' and 'color harmony'. These top features include two high-level and one mid-level attribute, a finding that is consistent across SHAP analyses of other ML models. This approach naturally raises the question: Why would we prefer these ML models over linear regression, a standard in psychological research? In response, we present linear regression results and discuss scenarios in which alternative ML models are more suitable. We highlight the benefits of SHAP analysis and examine the implications of interpreting linear regression results, especially when they fail to meet linear regression assumptions, which can potentially lead to incorrect conclusions. Our ML models, free from strict assumptions, can handle non-linearity and feature interactions. Overall, by employing multiple models and systematically analyzing results with SHAP, we establish both a reliable interpretation and a straightforward approach.

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Simulation-based Investigation and Mitigation of Visual Discomfort in AR/VR Environments

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The proliferation of Virtual Reality (VR) and Augmented Reality (AR) technologies is expected to revolutionize various sectors of our everyday life, from telepresence and tourism to education and healthcare, but also to have an impact in industrial applications like manufacturing, architecture and engineering construction. However, to render this technology usable on a daily basis, faces a significant challenge: the onset of discomfort experienced by users. Investigating and probing discomfort on devices is a complex issue due to the interplay of numerous contributing variables and the difficulty in measuring or controlling them. To address this challenge, we present a novel simulator developed within the Unity3D framework. It employs platform features, including using camera-captured images as render textures and custom shader transparency control. This enables faithful replication of real-world 3D technology displays within the virtual environment and allows the emulation of different configurations, such as immersive VR experiences, pass-through AR and see-through AR, all while offering full and accurate control over rendering parameters. This versatile simulator is compatible with a range of platforms, from 3D monitors to Head-Mounted Displays and aims at serving as a comprehensive tool for dissecting the complexities of visual discomfort in AR/VR environments. Through selective manipulation, it enables a thorough assessment of different factors such as time latency, optical distortion, and display alignment. To validate its utility, we conducted a pilot study on tolerable vertical misalignment of displays in a simulated see-through environment. Our findings closely resemble previous research outcomes reported in the literature, confirming the usability and effectiveness of the simulator. In conclusion, this innovative simulation tool proves to be a functional asset in the quest of investigating and quantifying visual discomfort in AR/VR settings. In addition, such a controlled experimental environment may facilitate the exploration of potential solutions and mitigations for seamless and immersive AR/VR interactions.

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Exploring the relation of locomotion patterns and visual disease: insights from deep-learning analysis

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Background: Falling risk among elderly is a significant concern, especially in visual diseases, such as glaucoma, a leading cause of irreversible blindness. Here we used an innovative approach to investigate this topic, i.e. the assessment of temporal information from videos of treadmill-walking participants (glaucoma vs controls) with deep-learning methods. Methods: To explore gait dynamics, we utilized videos of treadmill-walking participants with glaucoma (n=18, aged 62-82 years) and age-matched healthy controls (n=30, aged 64-83 years) from a previous study, which reported a similar effect of locomotion on visual function for both groups (Beyer et al. 2023). In those videos, participants engaged in treadmill walking during tests of visual function performance, both in static and dynamic conditions at 3.5 km/h walking speed. Participants were classified based on: i) clinical diagnosis of glaucoma, and ii) retinal structures (optical coherence tomography, OCT). This allowed for a multifaceted gait examination. Subsequently, deep-learning models were trained for classification by using spatio-temporal horizontal (xt) or vertical (yt) slices, sampled with a strategy based on saliency, instead of using just spatial frames (xy). Results: Our study revealed similar movement patterns in glaucoma and controls possibly attributed to the early nature of visual impairment in the disease group of our study. However, the model trained with horizontal slices showed differences of groups based on the OCT classification with about 80% accuracy. Moreover, this difference was also evident during the static condition. Conclusion: The absence of a group-difference in the current analysis mirrors the previously reported absence of a differential effect of locomotion on visual function in the same participants. Interestingly, an OCT-based participant classification appears to be supported by information from the locomotion videos. Overall, our study provides a novel approach on gait assessment, offering insights on the interaction between visual impairment, retinal structure and locomotion.

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Detecting objects in noise: signal pooling within and across objects

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The proportion of signal elements required to detect a global signal in noise was measured to examine how local orientation information is pooled within and across object regions. Stimulus arrays comprised oriented Gabors (N=400) positioned randomly in a 20x20 lattice. Orientations determined whether elements were signal or noise. Circular signal regions were defined within the array and were nominally subdivided into circumferential elements ('contour') and 'texture' elements (positioned randomly within). Signal Gabors for 'contour' had orientations tangential to a circle; 'textures' had orientations either 'radial' to the centre of the disc or perpendicular to it ('concentric'). Displays contained one type of signal (e.g. 'radial texture' or 'contour'), a combination of two (e.g. 'radial texture' enclosed by 'contour' forming a 'disc') or multiple regions (e.g. four 'texture' regions). Threshold sensitivity was measured as the minimum number of signal elements for detection. For single signal regions, thresholds increased with area following a power-law relationship for 'texture' and 'disc' but remained constant (~9 elements=2.5% SNR) for 'contours'. Sensitivities for 'contours' were between two (8.7 'contour' elements vs 17.0 'texture' for 1.9deg radius) and three (9.2 vs 31.5 for 5.7deg) times lower than for 'textures'. Manipulating presentation time affected all conditions equally: thresholds improved by about 50% between 24 and 250ms, then asymptoted. Spreading signals across four regions increased the number of elements at threshold by factors of 2.7, 2.9 and 2.3 for 'contour', 'texture' and 'disc'. Increasing the area of single regions, however, raised thresholds only by 1.0x, 1.7x and 1.6x. Sensitivities were largely independent of the separation of signal regions. Results are consistent with variable pooling efficiency: highly efficient summation when signals are positioned within annular regions ('contours'); efficient summation within circular regions and least efficient across regions. Comparing data with predictions of signal integration models provides insight into underlying computational strategies.

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The role of expertise and training in suppressing task-irrelevant sensory input

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It would be adaptive to attentively process as many sensory inputs as possible in order to get a detailed impression of the environment. However, attentional resources are limited and attentive processing must be prioritized for sensory input relevant to a given task. This may result in attention suppressing the processing of concurrent task-irrelevant sensory input in order to shield the processing of task-relevant input from distracting stimuli. However, how are task-relevant and task-irrelevant sensory inputs processed in participants with high attention skills? Such "attention-experts" might either be very good at suppressing task-irrelevant sensory input, or they might have sufficient resources to process task-relevant and task-irrelevant sensory inputs simultaneously. Here, we tested which of these two hypotheses applies to experts in the attentive tracking of independently moving visual objects. Previous results with non-experts showed that attention suppressed the processing of task-irrelevant vestibular motion cues in the parieto-insular vestibular cortex (PIVC), a core area of the vestibular cortex, while performing a visual multiple object tracking (MOT) task with high attentional load. Using functional magnetic resonance spectroscopy, we found that experts in visual attentional tracking (n=15) exhibited low levels of gamma-aminobutyric acid (GABA) (i.e., weak suppression) in PIVC while performing MOT with high attentional load. This is consistent with the hypothesis that experts have resources to simultaneously process task-relevant and task-irrelevant sensory inputs. To test whether non-experts can achieve a similar level of suppression of task-irrelevant sensory input as experts, we measured non-experts (n=20) who underwent behavioral training leading to expert-like performance in MOT. The results showed that GABAergic suppression in PIVC decreased to levels similar to experts after training compared to before training. Taken together, this suggests that attentional expertise is associated with a greater ability to simultaneously process task-relevant and task-irrelevant sensory inputs, rather than better suppressing the irrelevant input.
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Whac-A-Mole – Learning Rational Temporal Eye and Head Movements in Virtual Reality

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In 2016, Hoppe and Rothkopf demonstrated in a monitor-based experiment that people adaptively adjust their eye movements based on learned temporal regularities of an environment. In a conceptual replication, we conducted a virtual reality study and expanded on their task by incorporating head movements alongside eye movements as an additional requirement to solve the task. There were two event locations, situated to the left and right of the participants. Their objective was to detect a mole that appeared randomly at either event location after a randomized duration. Depending on the condition, event durations on both sides were varied, with moles appearing for either 0.5 (short), 2.5 (medium) or 4.5 seconds (long). Employing a block design consisting of 20 trials per block, participants were exposed to all possible combinations of event durations. For instance, in a long-short block, moles appearing on one side always lasted a long duration, while disappearing quickly on the other side. We expected participants to learn and adapt to the temporal regularities within each block, leading to increased fixation times at event locations with shorter durations and decreased fixation times at locations with longer durations. This strategy would optimize mole detection while minimizing effort caused by head and eye movements. We tested 30 participants in three versions of the experiment, providing minimal instructions (n = 10), detailed instructions

hinting to a strategy based on event durations (n = 10), and additional monetary rewards (n=10). In line with Hoppe and Rothkopf we found increased detection performance with longer presentation times. However, we only found the expected adjustments in fixation times in four participants. Our results suggest high individual variability in head movements and fixation behavior that may depend on the event duration times, the experimental environment, and other experimental properties, which we will investigate in future experiments.
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An active inference account of the formation of visual preference

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Although many of our behaviours and choices are guided by our preferences for certain experiences or stimuli over others, our understanding of how these preferences develop and are established remains elusive. Here, we investigate several possible mechanisms for the formation of visual preferences within the framework of active inference. Active inference proposes a unified framework on adaptive behaviour, suggesting that learning, perception and action interact to reduce the gap between an organism's current state and adaptively optimal states, which is measured using the notion of surprise. Within this framework, we show that the imperative of reducing surprise and achieving rewarding states (hedonic foraging) leads to the development of visual preferences. Specifically, we illustrate how active inference elucidates the mechanisms by which mere exposure (the repeated presentation of stimuli) and efficient coding (optimizing information content while minimizing metabolic costs) contribute to the development of visual preferences. We further explore the connections with both developmental (ontogenetic) and evolutionary (phylogenetic) processes. To illustrate these findings, we consider the example of preference for scale-invariant visual stimuli—e.g., a portrait with the Fourier statistics of natural scenes even if the model face is not scale-invariant. We also demonstrate how preferences can be reversed when the relative frequency of exposure is altered, particularly when exploratory behaviour is encouraged by heightened curiosity. Together, our work suggests that core biological adaptive mechanisms common to all organisms (e.g., homeostasis) may underpin the formation of preferences for simple, everyday objects to sophisticated cultural objects.
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Explaining the Disparity Sensitivity Function with Natural Image Statistics

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The human perception of depth and 3D shape from binocular disparity depends upon multiple mechanisms, including neurons responsive to absolute and to relative disparities. These mechanisms show tuning to disparity variations at a range of spatial scales, which we refer to here as disparity frequencies. Analogous to the perception of luminance-defined stimuli, this tuning is commonly referred to as the disparity sensitivity function. To examine how such disparity frequency tuning supports perception, we measured disparity sensitivity functions for different disparity-defined waveforms both with and without additive Gaussian distributed disparity noise. Participants were presented with random-dot stereograms containing disparity-defined sinusoidal, square, triangular, and sawtooth waves in a 2-alternative-forced-choice orientation discrimination task, where participants were asked to judge whether the waveform was oriented clockwise or counter-clockwise from vertical. Disparity amplitude was varied using a weighted up-down staircase to obtain discrimination thresholds for disparity frequencies between 0.4 and 2.5cpd. Peak sensitivity for all waveforms was around 1cpd, with square, triangular, and sawtooth waves exhibiting an increased drop-off in sensitivity at higher disparity frequencies, compared to sinusoidal waves. This decrease in sensitivity is also evident in high-noise thresholds, where square, triangular and sawtooth waves show reduced processing efficiency at upper and lower ends of the disparity sensitivity function. We relate these results to the disparity statistics of natural scenes, showing how such statistics can be used to recover the tuning properties of populations of relative disparity and disparity frequency selective neurons, providing an efficient coding account of human disparity frequency sensitivity.

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Experimental design and stimulus duration selectively modulate repulsive and attractive history effects

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The prevalence of attractive (i.e., serial dependence) and repulsive (i.e., adaptation) effects may depend on affordances provided by experimental designs and task types. When subjects need to differentiate a stimulus feature from its predecessors, the visual system may become sensitive to that feature, resulting in repulsed perception. Conversely, when subjects need not differentiate among stimulus features, the visual system may become less sensitive, resulting in attracted perception and leading to erroneous continuity between sequential features. We hypothesized that attractive and repulsive effects could be modulated by asking subjects to respond to each stimulus or the second stimulus in a sequence of two. Moreover, these effects may vary depending on the type and nature of the response. To test these hypotheses, subjects participated in four experiments that varied the experimental design (i.e., trials having either one or two stimuli) and task type (i.e., subjects either freely adjusting a response cue or making a two-alternative forced choice). In each experiment, stimulus durations varied between blocks to test whether stimulus duration modulated attractive and repulsive effects. In all experiments, subjects responded to the orientation of a Gabor patch. Preliminary results show a prevalence of repulsion in

both adjustment and forced choice tasks when subjects responded to the second stimulus in trials with two stimuli. Repulsion was absent when the first stimulus duration was shorter than the second. In trials with one stimulus, attraction effects emerged along with repulsion effects. However, it is not yet clear how attraction and repulsion were modulated by stimulus duration and task type in these trials. To better understand the influence of these factors, subjective biases, orientation range, and duration between trials will be investigated in the remaining data collection and analysis.

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Paradoxical 3-D vision from 2-D stimuli during recovery from third-nerve palsy: a striking new finding

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Introduction: Extensive studies in the recent past have enriched our understanding of the interaction of depth cues in human vision. The present study describes a rare perceptual experience that challenges our understanding. Methods: These are the observations of a single observer (first author: TVP) while recovering from third-degree palsy in the right eye: a condition that compromised eye movements and produced diplopia. The condition improved steadily with full recovery around three months after onset. The observations were obtained for brief time periods of several seconds at a time over a ten-day period that started two months after the palsy onset. TVP managed to defeat diplopia during these brief periods by achieving proper fusion of the binocular stimuli. Results: Under proper fusion during these brief periods, TVP reported 3-D percepts with vivid depth, while viewing either static planar images or video sequences on a flat TV screen. These depth percepts, which were obtained when the same 2-D image was seen by the two eyes, were as vivid as those seen in a pair of stereoscopic images created by a 3-D scene from two different vantage points. The perception of depth was most striking for images with rich perspective cues, especially linear perspective. Conversely, depth percepts were not obtained with 2D stimuli that lacked perspective cues, such as abstract paintings, drawings, random-dot patterns, and some TV video sequences. The vividness and three-dimensionality was much more convincing than that observed with either synoptic or monocular viewing. In summary, stereoscopic perception was obtained without binocular parallax! According to two neuro-ophthalmologists treating third-nerve patients, there were no reports of such perceptual behaviour in their decades-long clinical experience. Conclusions: A possible explanation for this paradoxical perceptual phenomenon is that the visual system overcompensated as a result of the two-month deprivation of binocular stereoscopic input.

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Image memorability is not strictly visual

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Some images are consistently remembered better than others. This inherent image memorability can be predicted surprisingly well by a residual neural network which is sensitive to semantic image features (ResMem). Large-scale human data also suggests that memorability is mostly driven by semantic features. This raises the question whether image memorability depends on visual features or at least in part is independent of modality. Here, we tested whether the memorability of an image generalizes to its verbal description. We prepared verbal descriptions of 160 scenes from the OSIE dataset, following a standardized protocol. We then tested the memorability of the transcribed image descriptions in a separate sample of volunteers (n = 55). During an encoding stage, participants were tasked to classify a subset of 80 descriptions as referring to outdoor or indoor scenes. In a subsequent surprise memory task, participants were presented with the 80 target descriptions again, now intermingled with 80 additional lures. For each description, participants indicated whether they had seen it during the preceding encoding phase or not. Half of the targets and lures were descriptions of images with low ResMem memorability scores (0.64 +/- 0.04) and half of them descriptions of images with high predicted memorability (0.91 +/- 0.02). Recognition sensitivity (d') for descriptions was significantly higher when they were derived from images with high memorability ($t = 7.66$, $p < 10\text{-}9$). This finding provides clear evidence that image memorability is at least in part modality independent. We plan to additionally explore which features render image descriptions memorable and whether the effect can be observed in participants with congenital blindness.
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Investigating Attentional Bias Towards Emotional Faces in Depression: An Eye-Tracking and Heart-Rate Variability Study

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Reduced heart-rate variability (HRV) and negative attentional bias have been found in people with depression, but it is not clear if this is the case for everyone with depression or only for those exhibiting a more pronounced tendency to use maladaptive emotion regulation strategies. Set within Malaysia's culturally diverse context, our neuroscientific research aims to explore the influence of cultural and societal norms on emotional regulation in depression, providing a comparative perspective against existing Western-centric studies. Our investigation centres on two main objectives: Firstly, to analyse the eye movement patterns towards faces displaying various emotions (i.e. neutral, happy, and sad) in depressed versus non-depressed individuals, by quantifying differences in fixation duration and fixation count. Secondly, to elucidate the relationship between the negative attentional bias and both emotional regulation strategies and autonomic arousal, as evidenced by heart rate variability (HRV). In this experiment, we measured resting-state electrocardiogram (ECG) to record HRV as a baseline measure of autonomic arousal. Subsequently, participants performed the Attentional Response to Distal versus Proximal Emotional Information (ARDPEI) task and the emotional face-matching task. This multifaceted approach enables a deeper understanding of the cognitive and physiological mechanisms underlying depression. We predicted that depressive patients

would exhibit an increased heart rate variability and a disengagement bias (i.e., spending more time fixated on negative facial expressions) compared to control participants. This disengagement difficulty might be due to a heightened sensitivity to negative cues. The outcomes of this study have the potential to revolutionise the approach to diagnosing mental health disorders such as depression.
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The Influence Of Material Properties On Exploratory Procedures And Touch Patterns During Haptic Shape Perception

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Hand movements are critical in perceiving object properties through touch, and different movements are used to explore different properties. For instance, we indent things to determine their softness, and we trace our fingers along their contour to learn about their shape. In two experiments, we investigated how the material properties of objects affect the use of exploratory procedures (EPs) and touch patterns during shape perception. In experiment 1, we recorded participants' hand movements during shape perception, and the movements were categorised into different EPs. In experiment 2, we recorded participants' finger trajectory during exploration, and the dwell time and velocity were compared across different shape features. In both experiments, the participants explored one reference and two test objects with a single finger before selecting the test object that was most similar to the reference in terms of shape, and the shapes were either deformable or rigid. The results showed that participants consistently judged shapes similarly across conditions, suggesting that they were able to perceive shapes regardless of material properties. In experiment 1, we found that the use of EPs varied depending on the material properties of the object being explored and that participants utilised additional EPs when exploring deformable shapes. In experiment 2, we found that regardless of material properties, participants exhibited similar touch patterns across conditions. This suggested that they may have given more importance to certain shape features as being more informative and relied on them to form the basis of their similarity judgement rather than the overall shape. Overall, our findings suggest that individuals adapt their exploratory strategies and touch patterns during shape perception, tuning them to specific material properties and task demands.
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Comparison between reading acceleration and phonological trainings in Developmental Dyslexia: a tACS study

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Developmental Dyslexia (DD) is a neurodevelopmental multi-domain disorder affecting the ability to read fluently and accurately, with an estimated prevalence of 1 out of 10 individuals affected worldwide. A large body of evidence has connected visual deficits of DD to the magnocellular-dorsal (M-D) stream, which is involved in serial scanning of letters and visuo-spatial spatial attention, and would putatively rely on beta-band activity (15-30 Hz). Nonetheless, the current gold standard for DD treatment are phonological trainings, which aim to improve the ability to identify and process word sounds. Some visuo-attentional trainings have been proposed, but evidence is still scarce and no studies have directly compared training outcomes of phonological vs. visuo-attentional approaches. Also, no studies have tested the potential of beta-band neuromodulation in improving training efficacy. Here, we enrolled 37 young adults with DD, who were randomly divided into three groups. One group (DD1) received a bilateral parietal β-tACS (18 Hz) along with a visuo-attentional reading acceleration program (RAP), while the other two groups received Sham stimulation, one paired with RAP (DD2), and the other with phonological training (DD3). We administered a neuropsychological battery before and after the 12 training sessions to assess reading and related cognitive domains, with follow-up tests at 1- and 6-month. All groups showed increased reading speed after the training sessions in standardized reading tests, with improvements lasting at 1 and 6-month follow-up. Particularly, in working memory tests (digit span) we observed a specific improvement only in the tACS group compared to the other two groups, which persisted up to 6 months. These preliminary results suggest that visuo-attentional trainings have similar efficacy relative to phonological trainings in ameliorating reading in DD. Notably, they also show initial evidence of the utility of parietal beta-tACS in improving neurocognitive domains supporting reading.
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Continuous-feature foraging: estimating target selection biases using Bayesian statistical modelling

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Foraging demands continuous attention to target objects and engagement in decision-making to facilitate correct selection. Frequently used as a tool to study selective visual attention, analysis of human foraging behaviour is limited by the absence of precise measures of decision-making, for scenes with multiple targets. Standard measures, such as run statistics, are constrained by target volume and distribution, making it difficult to infer environmental aspects or delve into underlying cognitive processes. Continuous feature targets present an additional challenge, despite their prevalence in naturalistic scenes – i.e., foraging for food items such as berries, wherein items exist along a colour distribution and cannot be differentially categorized. In the current study, we apply a Bayesian multilevel model, which characterizes foraging as a procedure of generative sampling without replacement. This allows us to break behaviour down into biases that influence individual's target selection, such as target proximity, independent of the number of targets present. The model is applied to data originating from a feature distribution learning study, which aimed to investigate the specificity of visual attentional

templates – whether templates are tuned to probabilistic information, or specific feature value. The study involved a multi-target foraging task, with target objects drawn from a truncated Gaussian distribution, sampled from a linearized colour space of 48 isoluminant hues. The current model predicts which target participants will select, as well as explaining a substantial proportion of foraging behaviour in this paradigm. The results suggest increased likelihood of selection for (i) more prevalent colour values in the scene (ii) items that are close to the previously selected target, both spatially and in colour-space. By accounting for continuous feature values, we expand our ability to analyse naturalistic foraging behaviours.

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Investigating the neural mechanisms of visual crowding in the behaving non-human primate

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Visual crowding is a well-known phenomenon where the recognition of a target is hindered by the presence of nearby distractors. This has been investigated extensively in human psychophysical studies, but neural mechanisms are largely unknown. To address this gap, we conducted a study to relate neuronal activity and behavioral performance, in a non-human primate model, during target categorization in crowded displays. To establish a monkey model of visual crowding, we created a set of 2D amoeba-like shapes with three or four prongs at a variety of sizes. Monkeys were trained to categorize a target shape based solely on prong number, while ignoring the surrounding distractors. To engender effects of crowding, the target shapes were surrounded by distractors that varied in number and their similarity to the target. Distractors were either amoeba-like shapes (like the target) or circles. Concurrently, we used a high-density Neuropixels probe to record neuronal activity in area V4, an intermediate stage of the ventral visual pathway critical for object processing. Mirroring human psychophysical findings, animal behavioral performance decreased gradually with more distractors. Likewise, shape selective V4 responses (~70% of neurons, $p < 0.05$, one-way ANOVA) exhibited a decline in shape tuning correlation between 'target alone' and 'target + distractor' with increasing number of distractors. However, when circle distractors (perceptually groupable) were introduced, both behavioral performance and shape selectivity of individual neurons remained relatively robust even amidst distractors. Furthermore, low dimensional representation of population neuronal data revealed that responses to 3 and 4 prong shapes occupied distinct regions of the space facilitating their categorization. These results suggest that V4 population activity can effectively discriminate various shape categories especially when the target is salient, and the behavioral decision in a shape discrimination task may be made by decoding the collective activity of V4 neurons.

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Effects of light enhancement at 585nm on impressions of colors

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We investigated the effects of illumination with an enhanced light with wavelengths of approximately 585nm on impressions of colors. The author has been investigating the effects of wearing special glasses (posica (TM) sunglasses, Mitsui Chemicals) that attenuate light waves of 585nm on colors. Our previous study found that these glasses made a variety of chromatic colors appear more vivid (Nishikawa & Kitaoka, 2022). However, the colorimetric results only showed that the hue of many colors changed when light waves of 585nm were attenuated. It is unclear why participants evaluated the colors as appearing more vivid. Therefore, to further investigate the effect of light waves of 585nm, we researched impressions of colors when light waves of 585nm was enhanced and to compare them with the effects of other light wavelengths. Ten students (five females, five males; M age = 23.8 years) observed a color checker chart (X-rite) under five lighting conditions (standard illuminant D65, D65 with an enhanced light waves of 445, 520, 585 and 635nm). The results of evaluation suggested that, especially under illumination with an enhanced light waves of 585nm, the vividness of chromatic colors was greatly reduced compared to D65 and illumination with an enhanced light waves of 445, 520 and 635nm. Furthermore, for preference, the evaluation of entire color chart, red, green, and white decreased under illumination with an enhanced light waves of 585nm. Light waves of 585nm may have the effect of making colors subjectively appear dull, disliked and unpleasant. This result is consistent with our previous study, which showed that chromatic colors appear more vivid with the use of glasses that attenuate light waves of 585nm.

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Impact of accent on gaze structure in grouping and segmentation: An eye tracking analysis

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Perceptual organization (grouping and segmenting) is sensitive to stimulus-driven changes. A single accent can impact the overall fixational pattern. In our study, we conducted several eye-tracking experiments to examine the impact of minimal accents on the perception of geometric shapes. We used specially created stimuli groups where grouping and segmentation were tested without and with minimal accents (28 stimuli). We had 3 experimental groups with 1) randomized stimuli (n=12), 2) partially randomized stimuli where the stimulus without accents was presented first and then afterwards the same stimuli with accents in a randomized order (n=18), and 3) randomized stimuli series where participants were instructed to look on the parts of the image that pops out (n=20). The results showed that accents substantially changed the gaze patterns in all experimental conditions, but the degree of changes varied depending on the experimental group. In the segmentation stimuli, the accent decreased the number of fixations. In grouping stimuli, the accent induced axial gaze structure corresponding to the location of the accent. The instruction lowered the number of fixations for segmentation stimuli but increased for grouping stimuli. The variance of gaze distribution for stimuli with accents was smaller in conditions with partial randomization when compared to the randomized conditions. This study covers the baseline conditions of

grouping, segmenting, and perceiving accent that can be used in further studies, e.g., when examining and comparing distortions in visual processing in virtue of visuo-spatial impairments or neurodegenerative conditions.
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Estimating the centers of visual point clouds

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Given a point cloud (sample) drawn from a 2D probability density function (pdf), how does the visual system estimate the location of the center of the pdf? Given only the leaves, where is the tree? If the pdf is Gaussian, the mean of the sample is an estimate that is unbiased and minimum variance (UMVUE). If the pdf is not Gaussian, however, the sample mean need not minimize variance. In previous work (Ota et al, ECVP, 2020) we reported that observers used different rules of combination for different underlying pdfs and their rules were approximately unbiased and minimum variance. It is implausible that the visual system has a different rule of combination for every possible pdf and we sought a combination rule that matched human performance across different pdfs. The model: The visual system takes a two-steps process. The first step is segmentation where the visual system partitions points in the sample into a small set of clusters. In the second step, the visual system assigns weights to points that depend upon cluster membership. We test three assumptions of a possible two-step process by factorial model testing. Assumption 1: segmentation. We propose that the weight assigned to each sample point depends on the cluster it is assigned to. Assumption 2: global agreement. Each cluster is assigned a weight by global agreement of that cluster with other clusters. Assumption 3: numerosity. We consider another constraint where the relative weight of each cluster is affected by is numerosity N. The more points in a cluster, the latger the weights assigned to each point in the cluster. Assumptions 1 and 2 reproduce the human data well. However, a model without numerosity captures human data almost as well.

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Emotion Prediction and Precision-Weighing: Facial expression intensity influences reliance on prior expectations to perceive emotions

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Accurate predictions about others' impending emotional states have been shown to facilitate face emotion perception and may thus promote effective social interaction. 'Precision-weighting' theory proposes that we place greater reliance on prior expectations to help decode less reliable/precise sensory input. Facial expressions are often subtle, ambiguous, and fleeting, however we understand very little about how and when predictions are used in the face of varying emotional expression reliability. To address this, the current set of experiments adopted a cue-target paradigm using short, emotive sentence cues to set prior expectations on how a neutral target face would emote in response. On each trial participants read a sentence and were told to imagine it was something said to the neutral face presented alongside. When the face changed to expressive they categorised the face emotion using a simple speeded key press (angry vs happy in Experiments 1-2; disgust vs sad in Experiment 3). On half of trials each, the facial expression matched the emotion predicted from the sentence ('congruent') or mismatched ('incongruent'). Critically, faces changed to show a low or high intensity expression to provide low and high reliability sensory input respectively. The magnitude of the congruency effect (difference in RTs and errors on congruent vs incongruent trials) was used to index the degree of reliance on the sentence cue (i.e., precision-weighting), with larger congruency magnitude reflecting greater weighting. Across all experiments the congruency effect was significantly larger when expressions were low vs high intensity. Experiments 1 and 2 compared young and older adults respectively, providing further evidence that this effect generalized across age as well as across different emotion pairings. Our study provides the first empirical evidence for precision-weighting within an emotion prediction framework, and contributes to broader emotion theory debate on how much the face versus the context drives emotion understanding.
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Decoding sound content in early visual cortex of aphantasic individuals

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Listening to natural auditory scenes creates distinct neuronal activity patterns in the early visual areas of blindfolded and congenitally blind participants. The accuracy of these information patterns increases from foveal to far peripheral retinotopic regions in the early visual cortex (V1, V2, V3) with even stronger effects in blind participants. This functional organisation is predicted by primate anatomical connectivity, with cortical feedback projections from auditory and other non-visual areas preferentially targeting the periphery of early visual areas. In congenitally blind participants, visual feedforward processing is absent and top-down projections to the visual cortex proliferate, which could explain the stronger effects reported. In contrast, research in aphantasia suggests an impairment of some forms of feedback to early visual areas leading to a loss of visual imagery experience. This raises the question of whether sound decoding would be possible in early visual areas in aphantasia participants. We presented auditory scenes to 23 blindfolded aphantasic participants. We decoded sounds in far peripheral V1 and foveal V3. Our results contrast with previous findings in controls, which showed a peripheral preference in V1 and V2 and no foveal V3 decoding, and in the blind, which showed a peripheral preference across V1, V2, and V3, as

well as higher overall classification accuracy. We explored this difference by modelling eccentricity effects across control, blind, and aphantasia datasets, and with a whole brain searchlight analysis. Our findings suggest that the feedback of auditory content to the early visual cortex may be reduced in aphantasic participants. Reduced top-down projections might lead to less decoding of sounds and reduced subjective experience of visual imagery.
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Metacontrast Masking of Symmetric Stimuli

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Masking occurs when the visibility of a stimulus (target) is reduced by the presence of another stimulus (mask). Metacontrast masking involves a mask that surrounds the target without spatial overlap. Simultaneous presentation of target and mask (0 ms) facilitates target recognition, while at intermediate Stimulus Onset Asynchronies (SOAs) (20 – 100 ms) there is interference (type B masking). We explored metacontrast masking across different stimulus categories. In Experiment 1, we replicated the behavioral findings reported by Aydin et al. in 2021, using identical stimuli—a disk with a missing sector on either side and a ring of the same colour. In Experiment 2, both sectors of the disk could be missing (symmetric) or only one sector (asymmetric). Both experiments revealed an inverted U-shaped curve, with facilitation observed at a zero SOA. Experiment 3 introduced irregular octagons, symmetric and asymmetric, again showing an inverted U-shaped curve but lacking facilitation at zero SOA. Similarly, Experiment 4, using abstract irregular shapes, replicated the curve with no zero SOA facilitation. Our findings suggest that metacontrast masking extends to complex shape processing, including symmetry discrimination. The initial facilitation depends on integrating the shape of the mask and target into a unified percept, indicating a separate phenomenon. The results are consistent with the idea that metacontrast masking is linked to feedback processing, which is also critical for complex shape perception.
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Population receptive field size across cortical depth along the visual hierarchy

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In the visual cortex, population receptive field (pRF) size increases both with eccentricity and when moving up along the visual hierarchy. Previous functional magnetic resonance imaging (fMRI) and neurophysiology studies found that in the primary visual cortex (V1), pRF size varies across cortical depth according to a U-shaped function, with the smallest pRF sizes in central layers. This U-shaped pattern is thought to reflect the hierarchical information flow across cortical depth, where the information arrives in central layers and is further processed in superficial and deeper layers. However, it is still unknown how pRF properties are organized across cortical depth in later visual areas. Here, we use population receptive field modeling at ultra-high field (7T) functional MRI to investigate pRF size variation across cortical depth and along the visual hierarchy (i.e. V1-hV4, LO-1 and LO-2) at sub-millimeter resolution (0.8mm isotropic). Functional data preprocessing included thermal denoising, susceptibility distortion correction, motion correction and high-pass filtering. Both anatomical and functional data were upsampled to 0.4mm isotropic resolution. Anatomical images were co-registered to functional images, segmented into gray matter, and divided into eight equivolumetric cortical surface layers. Our results show that in V1, pRF size follows the expected U-shaped function with cortical depth. In V2 and beyond, our preliminary results did not reveal a clear U-shaped function potentially suggesting a different association between pRF size and cortical depth. This study brings new evidence on the laminar organization of pRF properties along the visual hierarchy that require further investigation.
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Biasing face matching decisions with prior judgements

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Face matching, that is deciding whether two face images are the same person is a widespread task, e.g. when a passport officer tries to match a traveller to their passport, or when the police try to match a criminal caught on CCTV to images stored on a database. Some face matching decisions are made by humans and others can be made by automatic face recognition (AFR) technology. In the UK, the Data Protection Act states and any decision made by an algorithm must be checked by a human and this is a potential source of error. Humans can be influenced by the prior judgements of an AFR system, which can lead to greater accuracy when the algorithm has made a correct decision, however it can reduce accuracy if the algorithm has made an incorrect decision. The current study investigated whether contextual information if the form of fictious judgements from other sources, e.g. humans with varying degrees of face recognition ability, would influence face matching decisions. Participants were presented with face pairs and different sources of contextual information, such as a judgement from a super recogniser, an AFR system, a forensic examiner, and another participant (with average face recognition ability). Results found that although participants were explicitly asked to ignore the prior judgements, they influenced face matching decisions and reduced accuracy when fictious judgements were not correct. Interestingly, in the average face recognition ability condition, the fictious responses only reduced accuracy when faces were different identities. These findings extend previous research that face matching decisions can be influenced by other sources of information, such as prior decisions made by humans, in addition to judgements made by AFR systems.

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Normative Data for Assessment of Face Cognition in Policing

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Establishing reliable means for assessment of facial identity processing (FIP) skills is important for theoretical development and across various applied settings. Existing studies have reported FIP assessment tools and provide data that (ideally) describe general populations. However, oftentimes, WEIRD populations are sampled, although individual FIP differences may be valuable for applied purposes, e.g. security-related domains. Currently, there is growing interest in deploying police officers depending on their FIP abilities, but cohort-specific normative data is lacking. Critically, whether FIP test performance differs between civilians and different professional groups is currently unknown. We present normative data derived from various police cohorts in Switzerland and Germany (N=2557) for three challenging FIP tests. These tests probe individuals' face perception and memory abilities (across realistic, i.e. age-dependent, and superficial image changes) and have been used to identify Super-Recognizers for law enforcement. For all three FIP tests considered, police officers' data were distributed similarly to those of previously reported civilians. We observed significantly better FIP performance among police officers compared to civilians. However, the size of the observed effect of cohort is small and could be attributed to the noteworthy difference in sample sizes. These differences preclude the investigation of additional factors that could have a moderating effect (e.g., age, experience). To definitively determine whether cohort-specific normative data are needed and advisable for policing requires further analyses and data acquired among larger civilian cohorts are required.
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Exploring neural correlates of visual saliency using electroencephalography

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When exploring visual scenes, humans move their eyes to direct the fovea to points of interest since visual acuity rapidly drops towards the periphery. This sequential sampling of the environment is driven by low-level features of the surroundings as well as high-level aspects such as goals and can be captured in so-called saliency maps. However, it is still debated how, when and where visual saliency is computed and represented in the human brain. To add to this debate, we explore potential neural correlates of saliency using co-registered electroencephalography and eye-tracking. We base our analyses on a pre-existing data set containing unrestricted viewing data from 33 participants on natural images. In particular, we investigate the influence of image saliency on fixation-related potentials. To investigate potential saliency effects on the level of single fixations, we use an existing state-of-the-art saliency prediction model (DeepGaze III) which combines traditional static saliency maps with the recent scanpath history. This results in conditional saliency predictions for single fixations and consequentially a saliency map that changes throughout the exploration of an image. We focus on three different aspects of the saliency maps: the saliency at the location of the current and the next fixation and the entropy of the saliency distribution. In our analysis approach, we combine the saliency predictions with Unfold.jl, a regression-based electroencephalography analysis toolbox. Using linear deconvolution and generalized additive modelling, the toolbox disentangles overlapping electroencephalography signals and can account for (non-)linear confounds. In our case, we incorporate different eye-movement properties including fixation duration, position and rank as well as incoming saccade amplitude. Our current analyses are explicitly exploratory and aim at giving a first description of potential saliency effects in electroencephalography signals and at generating more specific hypotheses which can be tested on a new data set, which we are currently collecting.
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Attractiveness influences memory for unfamiliar happy faces, but not for angry faces

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We see many new faces in our daily lives, but what features of faces contribute to make these memory representations? Previous studies have reported that face attractiveness, trustworthiness, and affective information improve memory for face identity. It is possible to assume that attractiveness and trustworthiness have a high social value, so the faces with high values of these traits are prioritized for memory. For affective information, it may indeed have automatically captured attention and enhanced face perception. However, it remains unclear how positive or negative emotion affects memory for the identity of faces and how emotion and attractiveness interact. The present study used an incidental learning paradigm and a recognition task to investigate how affective information and attractiveness influence memory for face identity. 10 different identities with 3 variable angle pictures and positive/negative facial expressions were used in the incidental learning phase. During the learning phase, participants were asked to focus on the line-length judgment task and to ignore the faces that were presented in the background of the task stimuli. After the learning task, all participants performed a recognition task. In this task, participants judged whether or not the presented frontal neutral face was identical to the person they had observed in the learning phase. Results showed significant differences in hit rates between angry and happy faces. Learning with angry expressions showed superior memory. In addition, to analyze the effect of attractiveness and emotion on face memory, a two-way

ANOVA of emotion (angry/happy) x response type (hit/miss) was conducted with the attractiveness of each face as the independent variable. The results showed the high attractiveness effect on memory for the happy face, but not for the angry face. It suggests that different features may have been used for memory with different affective status.
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How human-like are robots really?

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We want to understand whether the Furhat, a robot with projected face images, can be used as a tool in face perception research. Images on the robot are programmable and interchangeable and could bridge the gap between real life constraints and the limitations of a laboratory. It could help us strengthen existing models of human face processing, and perception of trustworthiness that can be applied to affective computing and robot/human interaction. This study aims to understand scenarios in which a face is perceived to be human-like, or machine/robot-like. Understanding the extent to which the Furhat is perceived to be human-like allows evaluation of its use as a tool for face perception research. Six image categories were created: i) human faces, ii) physical Furhat, iii) virtual Furhat, iv) 50% morphs between human faces and the physical Furhat, (v) 50% morphs between human faces and the virtual Furhat and vi) other robots (not Furhat). Participants are asked to rate each image on 6-point Likert scales for human likeness, machine likeness, and trustworthiness. Each image is shown embodied (on a bust) and disembodied (in isolation). Results will aid stimuli selection for a neurophysiological follow-up study.
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Using low-level features to predict similarity judgements for naturalistic images

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Visual perception is heavily influenced by the internalisation of the statistical regularities inherent in nature. One such regularity is the spatially-dependent relationship between individual image features (e.g., contrast) for two regions of naturalistic images, such that closer image regions have more strongly correlated image features. However, it remains unknown whether human observers' similarity judgements for image regions follow such spatially-dependent feature relationships. Therefore, we had participants (N=20) judge which of two isolated image regions belonged to the same scene as an initial standard image region. One of the two test images (the target) was cropped from the same source photograph as the standard, drawn from locations separated by varying displacement distances and azimuths. The second test image (the foil) was drawn from a different photograph, at the same relative spatial location as the target. Using a generalised linear multilevel framework, we found observers' performance was accounted for across spatial conditions using low-level feature relationships alone. In particular, we found phase-invariant structural information correlations to be a key predictor for participants' responses. This finding was reinforced in a second experiment, where participants (N=20) performed the same task for altered image regions. Specifically, here image regions were altered to contain only their edge-information or luminance-thresholded black/white pixels. Our findings suggest similarity categorisations for naturalistic image regions can be accounted for by low-level feature matching, without requiring the reliance on more complex image information. More broadly, the results suggest observers effectively use available low-level visual information to inform their perceptual judgements, even when embedded in complex naturalistic scenes.
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Slower Category Learning and Over-Specific Generalization in Adults with Autism: Psychophysics and EEG

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Individuals with autism are suggested to experience difficulties with categorization and generalization. However, studies empirically investigating categorization or generalization in autism have mainly focused on one process at a time, and neglected underlying neural mechanisms. Here, we investigated these perceptual processes in adults with and without autism, both at a behavioral and neural level. The study was completed by 38 autistic adults and 38 matched neurotypical individuals. By presenting shapes sampled from an artificial multidimensional stimulus space, we investigated whether participants can (1) be trained to categorize these shapes via feedback, and (2) generalize trained categorization to an extended version of the same stimulus space and a novel stimulus space. Moreover, we assessed the neural underpinnings of category learning in both groups via electroencephalography recordings. Findings show that both autistic and non-autistic individuals are able to categorize highly similar stimuli and to generalize this categorization after training. In addition, no significant differences in self-reported categorization strategy were found between the groups. However, in the initial stages of training and when generalizing to a novel space, autistic individuals were significantly less accurate. Reduced performance during initial training was significantly correlated with higher autistic traits. Reduced generalization correlated with higher self-reported intolerance to uncertainty. Electroencephalography recordings during training showed that autistic individuals had a significantly reduced amplitude in their N1 component after stimulus presentation and a reduced amplitude in their P300 component after receiving negative feedback. A reduced N1 component could be in line with less categorical processing in autism. The reduced P300 component in central regions of the autistic individuals was related to higher activation in the frontal regions, which could represent either more

explicit processing or higher saliency of prediction errors. This multi-level approach sheds new light on the mechanisms that underlie information processing issues in autism.
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Individual gaze shapes diverging representations in inferior temporal cortex

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Complex visual stimuli evoke diverse patterns of gaze, but previous research suggests their neural representations are shared across brains. Moreover, it has been shown that representations of complex visual stimuli in human inferior cortex (IT) can be decoded across brains using hyperalignment. We hypothesized that cross-brain decoding accuracy will be boosted when instructing participants to stop moving their eyes. Additionally, we tested whether interindividual differences in a range of gaze parameters predict the degree of representational divergence for a given pair of observers. First, we established that individual gaze varies in highly systematic ways, even for a directed movie (Shaun the Sheep). Then, we used functional MRI in a subset of participants (n = 19) to test how predictive inferior temporal representations of one observer were for those of another, in two conditions. Participants watched movie segments either freely moving their eyes or fixating centrally. Results showed that the amplitude of BOLD responses dropped significantly for central fixation compared to free-viewing ($t(18) = -5.29$, $p < .001$, across IT). Nevertheless, cross-decoding performance significantly increased from 36% to 64% ($t(170) = 30.19$, $p < .001$). Furthermore, pair-wise differences of gaze parameters in the eye-tracking session predicted the degree of gaze-induced representational divergence in the scanner. Specifically, the average Euclidean distance between gaze positions ($b = 0.32$, $SE = 0.08$, $t(149) = 4.06$, $p < .001$), as well as differences in the tendency to fixate faces ($b = 0.24$, $SE = 0.07$, $t(150) = 3.12$, $p < .01$) and text ($b = 0.17$, $SE = 0.07$, $t(150) = 2.19$, $p < .05$) significantly contributed to neural divergence. Taken together, individual eye movements enhance the neural signal evoked by visual stimulation, but also lead to more individual representational geometries of complex visual stimuli.
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Occluded motion trajectories before appearance and after the disappearance

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The permanence of an object is the experience that the object persists in time and space, even though the movement of the object within the visual field might be discontinuous. The permanence of the visual world is an important aspect of vision (Marr, 1983). Gibson (1979) described the experiment (Kaplan, 1964) with occluding edges in which the occluded surface was perceived to be present even after it was hidden, and the appearing surface was perceived to be present even before it began to be seen. However, how long before or after occlusion do we perceive its presence? This study examines this issue using two different tunnel effect motion patterns: the so-called tunnel effect pattern (Burke, 1952; Michotte, Thinès & Crabbé, 1964), in which the brightness of the moving object did not change during the motion, and the foggy pattern (Vicario & Actis-Grosso, 1997; Actis-Grosso, 2021), in which the brightness of the object changes, becomes homogeneous with the background and disappears during the motion. A foggy pattern differs from a geometric figure motion pattern in how it is occluded. The foggy pattern does not have distinct occlusion edges like the geometric figure pattern. The moving object gradually disappeared. However, unlike the original tunnel effect of both types, the start and stop of the movement are hidden and the middle part of the movement is presented. Our observers drew the perceived motion trajectories. All observers perceived the occluded motion behind the screen. The perception of the motion trajectory during occlusion was affected by how it was occluded. The occluded motion trajectory was perceived longer when the occlusion edge was obscured than when it was perceived.

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Social perception as (Bayesian) hypothesis testing and revision. Findings and Mechanisms.

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Recent proposals argue that people's ability to understand the actions of others emerges from a Bayesian-like hypothesis-testing and revision process that tests prior assumptions about the higher-order goals underpinning others' behaviour against the sensory evidence. Here, I review evidence for such an account from a series experiments, showing that people's visuospatial representations of others' actions are indeed biased towards people's prior expectations above these actions, derived from cues about the higher-order goal and mental states driving them. In these studies, participants saw brief presentations of actions and made spatial judgments about the hand's spatial locations, while we manipulated the prior expectations people had about the hand motions. Across tasks and stimulus sets, results reveal consistent biases in perceptual judgments, away from the hand's objective locations towards prior expectations of how the motions will develop. These biases emerged from both lower-order information from the actions themselves (e.g., observed kinematics), prior information about the forthcoming actions (e.g., whether the agent will reach or withdraw from the object, whether there an obstacle in the hand's path), but also from higher-order information about the mental states of the agent (e.g., the agent's goals, their potentially false belief whether an obstacle is in the hand's path). Together, these results are consistent with the proposal that observers test prior assumptions about other people's behaviour against the sensory evidence they receive from their actions, and that these expectations are derived from multiple cues, reflecting an integration of both higher-order information about the mental states driving the actions, as well as lower-order cues about the actions themselves. I will discuss potential mechanisms underpinning these findings.

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Thematic relations between objects get through the bottleneck of crowding

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Target identification in peripheral vision deteriorates when the target is surrounded by other stimuli. This phenomenon known as visual crowding has been demonstrated for a large range of visual features. Despite the inability to identify a crowded target, target features, such as semantic information may still be processed, and, for instance, induce semantic priming effects. Most studies of visual crowding have used simple stimuli without considering semantic variability of real-world objects. Here, we assessed how semantic information that objects may share influenced target identification in crowding. In particular, we investigated thematic relations (e.g.,"pen-notebook") that are particularly quick to identify for manipulable objects, especially when correctly positioned for action (pen on right for right-handers). We hypothesized that thematic relations between manipulable objects may survive crowding. All participants were right-handed (N=64). Stimuli consisted of 12 sets of 3 manipulable object images. Objects were either thematically related ("pen-notebook") or unrelated ("pen-hat"), and horizontally arranged in pairs. Thematically related objects were correctly positioned for action or not. Pairs were presented in isolation or flanked by meaningless objects (crowding condition) in the upper or lower peripheral visual field (6.2°) for 150 ms. After stimulus offset, a word was centrally displayed and participants determined whether it corresponded to one of the objects using the keyboard. In isolation, identification performance was higher for thematically related (86.5% correct) than unrelated object pairs (73%). In the crowded condition, unrelated objects were identified at chance (50.9%). Importantly, in the crowding condition, performance was better for thematically related than unrelated objects (57.4%). Taking into account differences in visual similarity in the model did not change the results. Surprisingly, we found no impact of action position on performance. Findings suggest that thematic relations, regardless of object position for action, can overcome the bottleneck of crowding and facilitate identification of manipulable objects.

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Creative drawings reveal features for superordinate object classification

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Visual classification of objects into superordinate classes such as "animal" or "plant" is computationally challenging because radically different items (e.g., "jellyfish", "cow") must be grouped into a common class. Still, we can not only classify familiar but also novel (unfamiliar) items–by having learned general features shared across class members. Here, we tap into participants' visual feature spaces by asking them to generate new (i.e., non-existing) items from a superordinate class. 16 participants drew members of 9 different superordinate classes (animal, building, clothing, furniture, household appliance, musical instrument, plant, tool, vehicle; 5 drawings for each class), "without drawing a particular example". Additionally, we also asked them to draw an object belonging to no familiar class. To test to what extent these drawings were perceptually valid class members, we asked another 16 participants to assign each drawing to one of the 9 class labels, or type in a new class, and rate their typicality. The classification yielded an average accuracy of 69%–compared to 10% chance level–and an accuracy of 89% for (familiar) control drawings. Performance was particularly high for unfamiliar animals, plants, buildings and vehicles. Virtually no drawings were grouped into none of the classes, even most of the drawings created to "belong to no familiar class". Average typicality was 4.9 for unfamiliar compared to 8.2 (range: 1-10) for familiar drawings. Thus, we identified novel items that are grouped in superordinate classes without being familiar members of those classes. To identify the visual features allowing us to do this, we asked another group of participants to label and name the parts of each drawing they would use for classification. Our results show that by learning superordinate classification we establish visual feature spaces that also allow us to draw novel samples–for example by recombining signature features of a class.
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How experimental research on human shape perception can help us understand the history of science

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Experimental history of science employs experiments to investigate issues in the history of science. An example is recreating an historically influential physics experiment to investigate historical techniques and theoretical assumptions. Here we use the dot-matching paradigm developed for shape perception to investigate the biological practice of homologising organs and structures. Prior to Darwin and lacking agreed-upon criteria, numerous biological homologies were discovered. Exemplary instances include mammalian forelimb bones and floral organs. It is commonly presumed that the initial establishment of morphological homologies stemmed from an intuitive perception of similarities, yet this presumption remains untested. Our hypothesis posits that pre-evolutionary naturalists utilized the common human capability to discern visually corresponding locations on differently shaped objects. We found that (1) lay participants indeed utilized this capacity when identifying "corresponding" locations. Furthermore, (2) these locations were statistically indistinguishable from those deemed homologous by pre-evolutionary naturalists and contemporary experts. Additionally, (3) exposing lay participants to images of intermediate organs influenced their judgments of correspondence, aligning with historical accounts suggesting that intermediate organs aided pre-evolutionary recognition of homologies.

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Does temporal regularity affect evidence accumulation during perceptual decision-making?

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Previous research has found that temporal regularities, established through predictive cues or rhythms, may guide temporal expectations and facilitate the processing of expected events in perceptual decision-making and target detection tasks. Our pre-registered study (N = 80) extends past research by examining the influence of temporal regularities, induced by rhythmic periodicity, on evidence accumulation during a perceptual decision-making task. Participants completed 160 trials of a decision-making task, in which they viewed eight discrete pieces of visual information (tilted bars of different orientations sequentially presented on a computer screen) and integrated them towards a final decision (i.e., reporting the average orientation of bars in the presented sequence). To examine how temporal regularity affects evidence integration, we manipulated the degrees of stimuli periodicity across four within-subject conditions; for trials in the baseline control condition, the interstimulus intervals between the presented bars were jittered within a pre-set range (125 to 375 ms), whereas the interstimulus intervals between presented bars were fixed at 250ms in the periodic condition. The two remaining conditions had an intermediate degree of temporal regularity, such that the interstimulus intervals between all stimuli were fixed at 250 ms, except for a single interstimulus interval being either shorter or longer than 250 ms, for the violation early and violation late conditions respectively. Contrary to pre-registered hypotheses, we observed no significant differences in the accuracy of participants' decisions between conditions, nor in the weighting they assigned to each piece of evidence in a sequence. Exploratory analyses found notable inter-individual differences in within-trial evidence weighting profiles, revealing underweighting of the earliest and latest evidence for a significant subset of participants (n = 51). We discuss the implications of our results for existing findings on the effects of temporal expectations, and more broadly, for theories of evidence accumulation in the decision-making literature.
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The impact of overall stimulus intensity and processing noise on decision accuracy

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Value-sensitivity refers to the influence of overall stimulus intensity on decision-making and metacognitive performance. Specifically, choices are made faster and with greater confidence when the overall stimulus intensity is higher. Value-sensitivity cannot be fully accounted for by purely relative models of decision-making that dominate the literature. Previous research has proposed that value-sensitivity arises because internal processing noise during decision-making scales with the overall stimulus intensity. Alternatively, other accounts have been suggested, which focus on characteristics of the decision architecture (e.g., lateral inhibition, urgency signals, collapsing boundaries) rather than the mechanical limits of information processing. Distinguishing between these competing accounts has proven challenging. Here, I discuss unique predictions made by models that rely on input-dependent noise. For instance, the models that rely on input-dependent noise predict unique quantitative trends in how accuracy changes as a function of overall stimulus intensity. Additionally, only the models incorporating input-dependent noise predict less accurate choices across both free-response and interrogation protocols. In contrast, models that rely on characteristics of the decision architecture exhibit less accurate choices only in the free-response protocol. Moreover, for models that rely on input-dependent noise, when participants engage in the same experiment twice (double-pass paradigm), their choices for conditions with higher overall stimulus intensity are expected to exhibit reduced consistency between repetitions, even when the alternatives are equal. Conversely, models that rely on characteristics of the decision architecture do not predict less consistent choices in the double-pass paradigm. Experimental findings involving a brightness discrimination task (N = 60), a value-based task (N = 66), and the reanalysis of eight previous datasets seem to rule out a causal role of processing noise in value-sensitivity. Furthermore, these results shed light on the relationship between overall stimulus intensity and choice. The implications of these findings are discussed.

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Elemental and configural stimulus control in multidimensional visual discrimination learning by pigeons

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A multidimensional discrimination task affords unique experimental and theoretical opportunities for advancing our understanding of discrimination learning. Sixteen compound stimuli were created from all the possible combinations of two stimulus values from four separable visual dimensions: shape (circle/square), size (large/small), line orientation (horizontal/vertical), and brightness (dark/light). Two groups of pigeons (Columba livia) were trained on go/no-go visual discrimination tasks with different ways of presenting the stimuli. In the first group, stimuli were presented in a random manner from the very beginning of discrimination training; in the second, stimuli were presented in a stepwise manner with increasing complexity. In a Multiple Necessary Cues (MNC) task (the first group), reinforcement was not guaranteed by attending to only some of the presented stimulus features; the discrimination task could be learned only by attending to all four stimulus dimensions. However, while learning compound multidimensional visual stimuli, the pigeons demonstrated dimensional stimulus control. Evidence of attentional trade-offs among the four dimensions was observed during discrimination learning. This finding raises intriguing questions regarding elemental stimulus control during the learning process and configural stimulus control as a result of mastering the multidimensional MNC task. In a Redundant Relevant Cues (RRC) task (the second group), attention to all features of a compound stimulus was not required. The task was arranged by presenting features that were

relevant or irrelevant. To solve the task, the pigeons could attend to any of the four dimensions (separately or together). However, they attended to only one dimension in the first stage. Furthermore, they attended to just one additional dimension in each of the three succeeding steps. Thus, where redundant information was available and using fewer cues reliably predicted reinforcement, pigeons optimised their attentional behaviour, selectively and efficiently processing the minimum number of dimensions to discriminate between the presented compound stimuli.

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The relationship between visual acuity and working memory

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Background: Working memory (WM) is the ability to encode and temporarily maintain information. There is some evidence that early perceptual processes make an important contribution to successful WM performance. However, basic visual contributions to WM are not yet fully understood. The aim of the study was to test the relationship between visual acuity and working memory. Methods: Twenty-six participants performed the Acuity-Plus test to measure visual acuity and contrast sensitivity. Then participants performed a visual lateralized change detection task, while we recorded EEG. This allowed us to test the degree to which visual acuity and contrast sensitivity can predict visual (P1 & N2) and memory related (contra-lateral delay activity (CDA)) event-related potentials (ERPs). Preliminary results: WM accuracy was significantly higher and reaction time lower for low load compared to high load trials. We also replicated previous findings of a larger N2 and a larger CDA load effect in response to contralateral compared to ipsilateral presented stimuli. Results show a significant positive correlation between visual acuity and CDA activity for both low and high memory load, and a significant positive correlation between contrast sensitivity and CDA activity for low memory load. Conclusion: This study confirms a link between both visual acuity and contrast sensitivity, and neural measures of WM maintenance. Our results highlight the importance of controlling for visual acuity and contrast in all cognitive experiments, but it also points to the importance of visual acuity for being able to maintain information over the delay period.
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Memory for Stained-Glass Windows is Not Affected by Light Patterns

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Due to its unusual ability to both transmit and reflect light, stained-glass is a unique medium for research into the effects of light on memory and attention. Although stained glass windows are designed to be memorable, it is known that movement of a light source can affect selective attention. Alternatively, static lighting may serve to highlight the window's features. Thus light through a stained glass window may adversely affect or benefit memory depending on its nature. We tested these ideas in two recognition-memory experiments using rendered images of entire windows. Lighting conditions were digitally manipulated to depict either 'static' or 'dynamic' lighting or diffuse lighting only. In Experiment 1, participants (N=48) were required to learn images of windows with dynamic or static lighting patterns and subsequently conducted a recognition memory test. We found no effect on performance (response times or accuracy) of the lighting conditions. In Experiment 2 (N=48) we used the same protocol and stimulus set to test whether a difference in memory performance was found to localised (e.g., a shadow of a bird flying across the window) or more global (e.g. shadow of leaf movement from a large tree) dynamic light patterns through the stained glass windows. Again, we found no effect of light movement or distribution on either recognition accuracy or response times. These results suggest the intriguing finding that the information in stained-glass windows is not disturbed by lighting patterns. Eye tracking studies helped to reveal whether dynamic or static lighting was effective at guiding spatial attention. Results suggest that lighting can affect the allocation of attention but that the semantic relevance of the highlighted feature also plays a role. Our findings suggest an unexpected interplay between the role of incidental lighting patterns and the functionality of stained glass windows as memorable depictions.

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Advance Task Preparation on Crossmodal Attention Switching in Older Adults: An fMRI Study

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In this event-related fMRI study, we investigated whether older adults benefit from advance task preparation in a cued attention-switching paradigm requiring switching between different sensory modalities. Participants identified the spatial location of relevant visual vs. auditory modality targets while ignoring spatially congruent or incongruent crossmodal distractors from the other sensory modality. We manipulated the cue-to-target interval (CTI, 200 ms vs. 2100 ms), reflecting advanced preparation, to investigate age-related differences in performance and neural activation. Behavioral results showed comparable switch costs between younger and older adults, with advanced preparation reducing the switch costs independently of age. Age-related interactions emerged in the spatial congruency effect, indicating that older adults struggled more to ignore distractors from other sensory modalities, irrespective of CTI manipulation. The blood-oxygen-level-dependent (BOLD) response depicted widespread activation in the frontal-parietal cortex, related to switch costs, with no significant age-related differences in activation regions. The interaction between CTI and switching revealed specific activation of the left angular gyrus in trials with short CTI, suggesting in trials with less preparation more target-driven control is required to integrate multisensory information and reorient attention to relevant information when switching modality. Further analyses contrasting interactions between CTI and age showed activation differences in the bilateral inferior frontal gyrus, the bilateral fusiform gyrus and the left middle occipital gyrus. The results demonstrated that older adults required greater target-driven control to compensate the interference in stimulus processing, leading to the absence of age-related effects on preparation effects and on switch

costs at the behavioral level. In summary, the brain activation related to the goal-directed execution process involved in task switch was comparable for both age groups, whereas older adults recruited additional brain areas to compensate the target-driven processing.
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Spatial biases in visual foraging: Investigating the effect of display structure on foraging direction

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In many visual foraging experiments participants are tasked with collecting targets that disappear upon selection (most commonly using a computer mouse) in two search conditions: feature search (where one factor distinguishes the targets from distractors) and conjunction search (where two factors distinguish the targets from distractors). A prominent foraging pattern that emerges in both search conditions is a 'reading-like' spatial strategy component, as participants predominantly select targets closest in proximity in horizontal and vertical directions. However, it remains unclear whether this foraging pattern is driven by a cognitive preference for items in cardinal directions (up, down, left, and right). An alternate explanation is that the foraging pattern is a by-product of a grid arrangement of the items in the foraging task. We aimed to explore this alternate explanation by examining foraging behaviour in feature and conjunction search conditions when items were displayed on a (i) classic grid, (ii) 45-degrees rotated grid, (iii) or uniformly random structure. We analysed the results using von Mises mixture models, the results of which suggest a strong influence of stimulus arrangement on foraging behaviour in all three conditions. We found (i) a cardinal bias in the grid structure conditions, (ii) a bias which matched the rotation in the rotated structure conditions (i.e., an oblique directional bias), and (iii) a weaker cardinal bias (predominantly in horizontal directions) in the random structure conditions. These findings indicate that the observed patterns of inter-target direction are predominantly driven by preferences to select nearby targets rather than a cognitive preference for following cardinal directions. As these results are based on target selection behaviour (i.e., mouse clicks), we will discuss how analysis of eye movement behaviour patterns collected during the foraging trials may help us further understand the mechanisms of visual foraging.
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Examining the neural bases of looking and seeing in visual search using event-related potentials

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Looking and seeing are separate processes that typically overlap in time. To examine their underlying neural bases, we use event-related potentials (ERPs) on a visual search task (Zhaoping and Guyader 2007) that enables us to separate the two processes. Observers searched for a uniquely oriented bar among many identically shaped bars in each of many images, each could be of type A-simple, B-simple, A, or B. In A-simple images, all bars are oriented 45 degrees clockwise or anti-clockwise from vertical; the target is uniquely oriented. Modifying A-simple images gives A images, when to each original bar is added an intersecting horizontal or vertical bar to make an 'X'. All the 'X's are identical to, although rotated from, each other, confusing normal observers and prolonging their response times to report the target. In this confusion, gaze position during search often reaches, but then abandons, the target to continue searching elsewhere. Modifying A images gives B images, when the target bar's orientation tilts just 20 degrees from the intersecting horizontal/vertical bar, making the resulting 'X' distinctly thinner, eliminating the confusion. Removing all the horizontal/vertical bars from B images gives B-simple images. Observers' gaze movements and electroencephalography (EEG) were recorded. We aim to identify ERP components for looking and seeing typically associated with peripheral and central vision. This can be examined by, e.g., contrasting the EEG waves between A and B images (since A and B share the same target saliency effects to guide looking but differ in confusion caused by seeing) and contrasting the EEG waves for targets near or far from the initial fixation location before the stimulus onset. Preliminary behavioral and EEG data suggest that our experimental design, with further data collection and analysis, should provide substantial information that we plan to report at the conference.
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Blindness to Absence of Color: Effects of Color and Spatial Layout in Natural Scene Images

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We experience a richly colored visual world in our everyday lives. However, when color is removed from a region within a scene image and the image is briefly presented, observers often fail to notice the colorless region (scotoma). This phenomenon, referred to as blindness to the absence of color, persists regardless of whether the scotoma is located centrally or peripherally. Previous research using signal detection theory (SDT) has suggested that this blindness primarily results from a conservative bias in responding "full color" (no scotoma) to the scotomatized images. This study aimed to explore how manipulations of color and spatial layout in natural scene images influence this bias and either contribute to or disrupt blindness. Observers were asked to detect a scotoma (7.6° x 6.1°) within one of the four quadrants of a natural scene image presented briefly (67 ms), rendered in either normal or complementary colors. The spatial layout was also varied by arranging image blocks in either regular (coherent) or shuffled (jumbled) configurations. Results showed that missing the scotoma was most frequent in spatially coherent images rendered in normal colors. Rendering the images in complementary colors or shuffling the image blocks reduced the rate of misses. These findings confirm that blindness to the absence of color occurs with natural scene images. SDT analysis indicated that the conservative bias, rather than sensitivity to the scotoma (d'), primarily contributed to blindness. The results revealed a significant conservative bias only with spatially coherent and normally colored images. In contrast, d'

was higher in the normal than in the complementary color conditions, but lower in the coherent than in the jumbled configurations. These findings suggest that both color statistics and global configurational contexts in natural scenes are crucial for inducing the conservative bias and for blindness to the absence of color.
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From repulsion to attraction in visual working memory

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Contextual biases are well known in visual working memory studies. For example, when participants memorize colors of two items, their reports for one of the items might be biased away or towards the other. Most theoretical accounts of such biases aim to describe the mechanisms behind them without providing a normative account of the biases, that is, without explaining why they occur. We recently proposed a new normative model to fill this gap, and now report the first empirical data from experiments that tested the predictions of the model. The 'demixing model' explains contextual biases as a consequence of the fact that observers have to disentangle neural signals corresponding to different items in memory. Interestingly, the model predicts that both attraction and repulsion can coexist when the level of neural noise differs between the memorized stimuli. In four experiments, observers memorized two simultaneously presented items (Gabor patches or color mosaics), while noise levels were independently varied between the two by manipulating contrast, spatial frequency, and eccentricity (for Gabors) or stimuli heterogeneity (for color mosaics). Crucially, we found that the effect of noise on the target item depended on the noise on the non-target item. When the noise levels on the target and non-target were the same, increasing the noise led to more attractive (less repulsive) biases. When the noise levels differed, increasing the target noise led to more repulsive (less attractive) biases. This effect was further moderated by target-to-distractor similarity. Our results support the predictions of the demixing model and provide a clue to understand the divergent bias patterns observed in previous studies. However, the full pattern of observed biases is more complex than predicted by the model, highlighting the need for future theoretical and computational work.

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Cognitive-load dependent effects of tDCS on the executive vigilance decrement: insights from aperiodic EEG activity

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Vigilance is crucial for various activities, from attending lectures to driving cars, and its inevitable decline over time can lead to severe consequences. One potential tool to mitigate this decrement is the use of transcranial direct current stimulation (tDCS). To maximize tDCS effects, it is crucial to select anatomically relevant target regions and activate neural connections within these areas through a behavioural task. However, subtle differences in the task, such as the cognitive load it induces, may result in different patterns of brain activity that, when potentiated by tDCS, can lead to varying behavioural outcomes. To better characterize the relevance of this aspect in relation to the decrement of executive vigilance (EV), participants (N = 180) received anodal tDCS over the right posterior parietal cortex during the performance of a task assessing EV and imposing varying levels of cognitive load (single, dual, or triple task). On-task electroencephalography (EEG) data was collected before and after stimulation and EEG power spectra were then parametrized to disentangle periodic (oscillatory) from aperiodic (non-oscillatory, namely aperiodic exponent and offset) components. Results showed that tDCS led to a decrement of the aperiodic exponent extracted from a 30-45 Hz frequency range, reflecting an increased excitation/inhibition (E/I) balance. This increased E/I balance was in turn associated with a mitigated EV decrement in the triple or high-load task (i.e., positive mediation), and an exacerbated EV decrement in the single or low-load task (i.e., negative mediation). These findings suggest a potential mechanism for cognitive-load dependent effects of tDCS, indicating that beneficial behavioural outcomes from increased excitability occur only when the stimulated region is primarily engaged in the task. This study highlights the nuanced interplay between brain state, task demands, and tDCS outcomes that should be considered for applications in future research or clinical translation.

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Goal-dependent spatial frames for working memory following body movement: a combined VR and eye-tracking study

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Working memory enables us to hold onto relevant visual information in service of anticipated future behaviour. Consequently, the goal for which information is retained may crucially drive the way we retain information in working memory. Using Virtual Reality in combination with eye-tracking, we investigated whether distinct tasks in moving participants prompt the use of distinct spatial frames that serve working-memory, even when presented with identical to-be-memorised visual information. Participants encoded two oriented bars (on the left and right) in working memory, then turned around (rotated 180 degrees) before being cued to either report the precise orientation of the cued memory item (report blocks) or manually reach back to the cued memory item (reach blocks). The 180-degree body rotation uniquely enabled us to disentangle two potential spatial frames used for working memory following rotation: a current-viewpoint-independent frame retaining a snapshot of the visual objects as seen at encoding vs. a current-viewpoint-dependent frame reflecting where the visual objects are in the external environment relative to oneself (updated with self-movement).Reporting and reaching data, together with patterns of fixational gaze behaviour, unveiled the use of distinct spatial frames for the two tasks. This reveals how a foundational aspect of working memory retention — the spatial frame in which memory content is retained — is critically shaped by the nature of the anticipated task, even when tasked to retain identical visual stimuli.

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A potential spectral code for subjective colour perception

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Colour experiences, normally elicited by coloured light, can also occur in the absence of physically coloured stimuli. Intense flickering white light applied to a uniform field (ganzfeld) can evoke hallucinatory colours and forms. The mechanisms underlying the phenomenon of flicker-induced colours are not well understood but may provide insights into the neural basis of colour perception in general. We aimed to investigate the correspondence between specific flicker frequencies and particular illusory colours. Participants completed a dichoptic matching task over two sessions. To one eye, we presented intense ganzfeld flicker using an LED stroboscope. To the other eye, we presented a disc on an LCD display with adjustable hue and saturation. In the first session, we asked participants to make matches while exploring the available flicker frequency range (3-38 Hz). Whenever participants observed hallucinatory colours at a particular frequency, we asked them to match all the colours they saw by adjusting the colour of the matching disc. In the second session, we presented the frequencies at which they had made matches in the first session and again asked them to match any hallucinatory colours they perceived. We analysed our data using a permutation-based approach, where we compared colour differences between matches made at the same frequency over the two sessions with colour differences between matches made at randomly selected frequencies. At the group level observed colour differences between sessions were significantly smaller than permuted colour differences, both for hue angle and for CIE u'v' Euclidian distance (both $p < 0.01$). At the level of individuals, there were significant differences for only a subset of participants. Our results imply that flickering white light presented at specific frequencies can reliably induce illusory percepts of specific colours. Our findings are consistent with a hypothesis that a temporal code could contribute to cortical colour representations.
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Neuronal mechanisms involved in filtering out a salient task-irrelevant signal in visual perceptual learning

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Task-irrelevant signals are ubiquitous in our visual world and interfere with the processing of task-relevant signals if they are not effectively filtered out. A particular challenge arises when task-irrelevant and task-relevant signals are paired over a long period of time, as inefficient filtering could lead to perceptual learning of each signal. Here we addressed three critical questions that are important for understanding how the brain deals with task-irrelevant signals. First, does the effectiveness of filtering depend on the perceptual salience of a task-irrelevant signal? Second, does the filtering of a task-irrelevant signal already occur in early visual areas? Third, which neuronal mechanisms are involved in filtering out a task-irrelevant signal? We trained 24 participants on a visual exposure task in which they were presented with a task-irrelevant signal (coherent motion in one direction) in the visual periphery while performing a relevant rapid-serial-visual-presentation task at central fixation for twelve sessions on separate days. In half of the participants, the task-irrelevant signal was perceptually weak (near detection threshold for coherent motion), whereas for the other half it was strong (highly salient). Functional magnetic resonance imaging and spectroscopy were conducted while participants performed the exposure task before the first and after the final training session. The results showed, first, that perceptual learning occurred for the weak but not salient task-irrelevant signal, second, activation in early visual areas increased with training for the weak but not salient task-irrelevant signal, and third, glutamate in early visual areas was lower before and after training for the salient task-irrelevant signal than for the weak one. This suggests that filtering out a salient task-irrelevant signal involves downregulation of glutamate in early visual areas, which may reduce neuronal excitability to this signal and thereby prevent perceptual learning from occurring. However, this filter mechanism fails with a weak task-irrelevant signal.
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The effectiveness of pointing- and gaze-cues in spatial attention

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Recent work suggests that the pointing hand on an outstretched arm is a more powerful cue than the gaze-cue, suggesting these social cues are not equal. The aim of this study is to investigate differences between gaze- and pointing-cues, looking specifically at saliency, spatial proximity, and trial context. A cartoon figure was designed to present four types of cues: 1) a gaze-cue, 2) a peripheral pointing cue on an outstretched arm, 3) a central pointing cue presented over the torso of the body, and 4) a flower cue matched for low-level features to the peripheral pointing cue. Cue validity was non-predictive, meaning there was no strategic incentive to follow the cue. To test the impact of trial context, different cue types were presented randomly within blocks (Experiment 1) or tested in separate blocks (Experiment 2). In Experiment 3, trials were mixed within blocks but the total number of gaze- and gesture cues were balanced, and stimulus-onset asynchrony was manipulated. Across all three experiments, the results showed that the pointing cue was a more effective cue than the gaze-cue. The impact of the pointing cue could not be explained by low-level salience or spatial proximity to the target. Trial context did affect the effectiveness of the gaze-and pointing-cue, suggesting that spatial cues are influenced by overall context and shaped by expectations. It is concluded that not all social cues are alike. While the label 'social' given to embodied cues like the gaze- and pointing-cue can be useful in descriptive sense, the predictive validity of this categorization is debatable.

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An investigation of square wave jerks in Parkinson's disease, progressive supranuclear palsy and healthy controls

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Progressive Supranuclear Palsy (PSP) is a neurodegenerative disorder characterised by parkinsonism, postural instability, cognitive impairment, and ocular motor dysfunctions. One of the criteria used for the diagnosis of PSP is the presence of square wave jerks (SWJ). The purpose of this study is to characterize the SWJ in PSP, Parkinson's disease (PD) and healthy controls (HC) to define a specific diagnostic cutoff based on this behaviour. A series of 40 healthy controls, 55 PD patients and 38 PSP patients performed a 5 second fixation task when eye movements were recorded. To determine the best predictor of PSP, different parameters of SWJ were compared. 60% of HC, 74% of PD and 94% of PSP patients perform SWJ with different amplitude and duration. With an AUC of 0.88 for PSP to HC and 0.78 for PSP to PD, the sum of all SWJ performed was found to be the best parameter to classify PSP to HC and PD respectively. Cutoff points that balance sensitivity and specificity are respectively 1.37° and 1.88°. The sum of SWJ amplitude can be used for PSP diagnosis. As a new video-oculographic biomarker, this index could be used in conjunction with vertical eye movements to differentiate PSP from PD and HC.

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Cézanne's Madame and Klimt's Dame – Serial dependence in appreciation of art portraits

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Serial dependence refers to the assimilation of recently perceived stimulus attributes into the computation of the current percept. Previously, we have reported that serial dependence in facial attractiveness judgements was greatly reduced when faces shown in succession differed in gender and a serial contrast effect was found when the nature of aesthetic judgement required changed across trials (attractiveness of faces vs beauty of scene). Here we asked whether serial dependence occurred in facial attractiveness and aesthetic merit judgments of art portraits and whether the gender of portrayed characters and the artistic styles of paintings interrupted the assimilation of judgements across trials. In a series of experiments, participants were asked to rate either the attractiveness of the portrayed characters or the beauty of the paintings in quick succession (4 identical blocks of 50 randomised trials). In one condition, all paintings were in the same artistic styles (either Baroque, Impressionist, or Expressionist) but the gender of the portrayed character could vary from one trial to the next; while in another, the artistic style, but not the gender, varied. Serial dependence was modelled as a function of the attractiveness or beauty of the immediately preceding painting and the difference in the average rating between the current and the preceding paintings. A positive assimilative effect was found in all conditions, although its magnitude was reduced for attractiveness (but not aesthetic) ratings for only Baroque paintings when there was a change in character gender in successive trials. Artistic style was also found to have similar modulating effects whereby a change in style attenuated serial dependence for both judgements. These findings suggested that serial dependence can be attenuated depending on the category membership (e.g. gender, style) of recently viewed stimuli and whether the categorisation process was relevant and occurs before an aesthetic judgement is made.
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Target selection during "snapshot" foraging

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This study was aimed to investigate the characteristics of attentional selection during foraging tasks. While previous studies have identified key variables that affect attentional selection, they are often influenced by the overall characteristics of the tasks. To address this limitation, we designed a foraging task that involves a sequence of local "snapshots" of foraging displays, allowing for tighter control of local target and distractor ratios while maintaining the essence of a sequential, multiple-target foraging task. During each snapshot, observers are presented with only six items, including varying numbers of two target types and two distractor types. After each selection, a new six-item array immediately appears centered on the location of the last selected target. We analyzed the data by comparing feature and conjunction-based foraging and examining the proportion of different target types in each trial. Our results indicate that the proportion of target types affects selection, with longer response times during conjunction foraging when the number of alternate target types is greater than the repeated target types. Furthermore, the selection of targets in each snapshot is influenced by the relative positions of previously selected targets and distractors. This study highlights the extent to which previous findings on foraging can be attributed to the changing overall statistics of the foraging array. The use of "snapshot foraging" in our study offers a promising method for enhancing experimental control and improving our understanding of how people select targets during continuous attentional orienting.

Symposium 1 - Increasing diversity in person perception research

Bias for White AI faces: A hyperrealism effect

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Faces are the linchpins of our social world, conveying people's identity, age, gender, emotions, and social intentions. However, the stimuli used to study face perception have often lacked diversity and ecological validity. Here, we present data showing that face perception

studies have over-relied on highly controlled stimuli, a method that neglects the complex and multifaceted nature of facial information integral to real-world interactions. We consider key examples that show how the inappropriate use of artificially posed expressions and computer-generated images has distorted scientific knowledge. Moving forward, researchers are being tempted to replace human face stimuli with highly realistic AI-generated images. While AI-generated images offer a chance to rapidly and cheaply improve stimulus diversity, their use still needs to be approached with caution due to potential biases and physical differences from human faces. Our work shows that White AI faces, but not AI faces of other races, appear more realistic than human faces—a "hyperrealism" effect—which we argue is due to racial bias in algorithm training datasets. Our work also shows that there are still physical differences between AI and human faces, which humans are sensitive to but misinterpret in AI face detection tasks. We conclude by discussing how to ethically leverage the promising new AI image generation tools in vision science, with a focus on preserving scientific integrity so that we might truly advance understanding of human perception.

Capturing variability in child faces using an artificial, but highly realistic set of children's faces

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There is a growing call for face perception research to use more naturalistic images to better represent the faces we see in everyday life. Face stimulus sets that include naturalistic images are becoming increasingly common, but children's faces are still underrepresented. To increase the availability of child faces for research purposes, we created the Artificial Child Face Database, a set of 500 artificially generated yet highly realistic images of children. To validate the faces, adult participants estimated the age, gender, race, and emotion of the faces in the database. The images are diverse in age (3-11 years) and race (representing 15 different racial groups). While AI-generated images offer a large and diverse sampling of faces, they also present their own set of challenges, such as ethical issues with how images are selected for training algorithms and questions surrounding whether perceptions of AI faces are comparable to those of real faces. In the preceding presentation, A/Professor Amy Dawel will discuss the physical differences between AI and human faces. Building on this discussion, our study examines differences in the social impressions children and adults form of AI-generated children's faces from the Artificial Child Face Database, varying in emotional expression, ethnicity, and age to real but tightly controlled images of children's faces. Our work highlights the importance of increasing the diversity of child face stimuli while also addressing the ethical challenges associated with sourcing images of children for research purposes.

Does diversity in facial age influence first impressions?

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When participants view images comprised exclusively of young or older adult faces, a two-dimensional model (trustworthiness, dominance) of first impressions emerges. When naturalistic images that vary in age are used, a third dimension (youthful/attractiveness) emerges. It is unknown whether this third dimension is attributable to naturalistic images, or to diversity in face age. In daily life older adults are often encountered among young adults—a context that might increase the role of age stereotypes and influence first impressions. The present study examined whether diversity in face age influences spontaneous first impressions of young and older adult faces. Young and older adult participants (n=634) provided written, spontaneous first impressions in one of three conditions: older faces, younger faces, or intermixed. Stimuli were highly controlled with neutral expressions. Utilizing a natural language processing approach, participant responses were coded into stereotype content dictionaries (warmth, competence, appearance, health, emotion). We measured the proportion of responses that fell into each dictionary, and the valence (positive/negative) of each response. A similar pattern of results emerged across participant age and condition. The proportion of responses varied as a function of face age for four dictionaries (higher for younger faces for the competence and appearance dictionaries; higher for older faces for the health and emotion dictionaries). There was minimal evidence that face age influenced valence. These findings are consistent with dimensional theories of first impressions. Warmth/trustworthiness emerges as a primary and stable dimension across both face age and perceiver age, while the second dimension (here, competence) varies with face age. Our findings suggest that diverse stimuli elicit subtle differences in first impressions, with references to appearance and health (aspects of youthful/attractiveness), as well as competence, varying across face age. Diverse and naturalistic stimuli in research on visual and perceptual processes is essential to increase generalizability.
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First impressions from faces and bodies

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Faces and bodies serve as canvases for our snap judgments of others' personalities, but how do these visual cues combine when we form these impressions? This study delves into the interplay of facial and bodily information in shaping our first impressions. Experiment 1 demonstrates that the contribution of faces and bodies to whole-person perception varies with the trait judged: agreeableness traits are inferred primarily from faces, conscientiousness traits from bodies, and extraversion traits from the whole person. A control condition confirms that both clothing and body shape influence whole-person judgments. Experiment 2 reveals that the context of the whole person biases ratings of faces and bodies, suggesting that our judgments are skewed by the broader visual context. These findings suggest a more intricate interaction between face and body trait perception than previously thought. A novel framework is proposed to explain the integration of face and body in trait perception, incorporating perceptual and nonperceptual determinants, trait formation, and integration, as well as factors such as the rater, the person rated, and the situation. This study reveals the subtleties in how we come to see and judge one another, underscoring the need to consider the traits under scrutiny and the context of these judgments. Building upon these insights, our study advocates for a more comprehensive framework that integrates context in face perception research, emphasizing the complexity and the critical need for diversity in the study of vision and perception.
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Symposium 2 - Statistical learning in visual perception: How does the visual system process probabilistic information in the environment?

Learning Environmental Statistics with Feature Distribution Learning

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The visual world might look chaotic as it varies from moment to moment and from one location to another. However, there are certain regularities. Leaves on a tree might have green-yellow hues, while the sidewalk would be mostly gray. In other words, the features of different objects correspond to different probability distributions. In the last decade, a series of studies have used a new behavioral approach coined Feature Distribution Learning (FDL) to study how such environmental statistics are learned. In this approach, observers perform an odd-one-out search task with distractor features in each trial drawn from a given probability distribution for several trials. Afterward, in a test trial, the experimenter varies the similarity between the search target and previously shown distractors. Changes in the search times in test trials then reveal how observers represent distractor feature distributions. In this talk, I will review the major findings obtained using FDL: (1) that people can learn feature distributions quickly and with surprising accuracy; (2) that this approach is more sensitive than explicit tests, such as 2AFC, in testing the knowledge of feature distribution properties; (3) that observers combine information about distributions of different features and their locations; and (4) that these distributions affect our perception. I will also highlight some of the apparent limits to what can be learned about environmental statistics and discuss the outstanding questions.

Explicit Attentional Goals Unlock Implicit Spatial Statistical Learning

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In visual search, research often focuses on top-down or bottom-up drivers of attention. However, past experience can also be important in shaping attentional guidance. In probability cuing, people quickly learn probabilistic spatial distributions of targets and develop attentional biases to target-likely regions. These statistically learned implicit spatial biases have been shown to be persistent, where the bias developed in one visual search task can transfer to other visual search tasks. However, in the real world our targets change frequently, suggesting that our spatial biases should be able to quickly update based on our goals. In this talk, I will provide evidence for goal-specific probability cuing, where spatial biases are updated on a trial-by-trial basis depending on the search target. This work challenges existing attentional theories, as it shows the target template is not merely a currently activated target representation in working memory. Our template also activates associated spatial information gained through implicit statistical learning, which helps guide attention. This work is also important to the probability cueing literature, as it shows that although statistically learned implicit biases may be persistent and inflexible in certain contexts, our goals can flexibly activate these biases. This highlights how goals may be a critical determinant of when implicitly learned information is utilized in task performance. As our targets in the real world are often defined by category (e.g. grab the mug), we expected the spatial priority map learned for specific exemplars from a category to transfer to other category members. This is what we found. Therefore, this type of fast statistical learning of spatial associations may underlie some of the benefits found in visual search in scenes. On the whole, our research shows explicit search goals can unlock implicit probability cueing, providing a flexible integration of goals and statistical learning to guide attention.

Location cueing from color distributions

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Our visual system shows great ability at picking up statistical regularities in the environment. One example of such a mechanism would be probability cueing, where the location of a target can be predicted based on its spatial regularities. However, the extent to which priority mapping of the target depends on the context properties is still largely unknown. Here we investigated whether differences in color ensembles can be used as a cue to detect statistical regularities in target location. In our first experiment, 39 participants searched for an oddly colored target in a 6 x 6 set of colored diamonds. On each trial, the set was drawn from one of two color distributions centered on different color averages. Each distribution was associated with different target location probabilities, with an 80% chance that the target would appear on the left side of the display for one distribution, and on the right side for the other distribution. We found that, in the second half of the experimental session, participants were faster at locating the target and, crucially, they were the fastest if the target appeared in the high probability location corresponding to the current colored ensemble. In a second (24 participants) and third experiment (15 participants), the performed task was the same, but this time, the distributions had different variance while being centered on the same color average. In both experiments, we found no evidence that search times were faster when the target appeared in a high probability location. These results show that different priority maps can be assigned to targets depending on the context properties, but also reveal important limitations to such learning.

Learning spatial statistics to resist distraction by color singletons and luminance transients. Different mechanisms?

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Efficient search requires that we direct our attention towards targets and ignore other salient objects that might distract us. Conveniently, in a familiar environment we can learn to expect where salient distractors might appear, and use this information to better ignore them. This form of statistical learning is evident in the additional singleton paradigm, where observers look for an oddball shape while attempting to ignore color singletons that occasionally appear within the search array. If a color singleton appears in a display region where distractors are frequent, distraction will be weaker (Distractor Location Effect). Conversely, if a target appears in that

region, responses will be slower (Target Location Effect). This may indicate that statistical learning leads to suppression of the distractor-associated location in a priority map where stimuli compete for attention, also consistent with the finding that distraction is maximal when color singleton distractors and shape singleton targets appear nearby, a possible sign of enhanced competition. But does this explanation hold also in the case of distractors that appear suddenly and in isolation, i.e. without simultaneous competition from other stimuli, specifically luminance transients? After replicating the findings with color singletons, in the case of luminance transients we found again a significant distractor location effect, but no target location effect and reduced costs when distractor and target were near. We interpret our results as indicating that in the case of luminance transients, in the absence of competition, experience is not used to reduce distraction by means of suppression in a priority map. Instead, the costs associated with re-orienting attention towards the target, after capture has taken place, might be reduced. Our findings confirm that experience can help us to cope with distraction, but this is achieved through different mechanisms and at different levels depending on the specific stimuli and task constraints.

High-level prediction errors in low-level visual cortex

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Perception and behaviour are significantly moulded by expectations derived from our prior knowledge. Hierarchical predictive processing theories provide a principled account of the neural mechanisms underpinning these processes, casting perception as a hierarchical inference process. While numerous studies have shown stronger neural activity for surprising inputs, in line with this account, it is unclear what predictions are made across the cortical hierarchy, and therefore what kind of surprise drives this upregulation of activity. Leveraging neuroimaging techniques, such as fMRI, and visual dissimilarity metrics derived from a deep neural network we arbitrate between two hypotheses: (1) prediction errors may signal a local mismatch between input and expectation at each level of the cortical hierarchy, or (2) prediction errors may be computed at higher levels and propagate down the visual cortical hierarchy. Our results are in line with the second hypothesis. Prediction errors in both low- and high-level visual cortex primarily scaled with high-level, but not low-level, visual surprise. This scaling with high-level surprise in early visual cortex strongly diverges from feedforward tuning, indicating a shift induced by predictive contexts. Mechanistically, our results suggest that high-level predictions may help to constrain perceptual interpretations in earlier areas thereby aiding perceptual inference, and thus bolster a core hypothesis of hierarchical predictive processing theories, that predictions are relayed top-down to facilitate perception.

Talk Session 1 - Motion Perception

Perceived Speed-in-Depth is Affected by Adaptation to Binocularly and Temporally Anti-Correlated Stimuli

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The theory of efficient coding provides an alternative account of binocular coding, whereby disparity-sensitive neurons operate through two channels: one that sums left and right eye inputs, and one that takes the difference. We applied this model to an investigation of motion-in-depth perception, selectively adapting these channels in a 2-alternative-forced-choice speed-in-depth discrimination task. Participants adapted to binocularly and/or temporally correlated and anticorrelated 1/f noise patterns at a range of temporal frequencies, with adaptors presented above and below fixation, counterbalanced across blocks. Following adaptation, participants were asked to judge which of two random-dot surfaces had the faster motion-in-depth, with responses used to recover psychometric functions for speed-in-depth discrimination. Under an efficient coding account, an anticorrelated stimulus should preferentially adapt the differencing channel, leading to a reduction in perceived speed. Conversely, a correlated stimulus should adapt the summation channel, leading to an increase in perceived speed. Our results were consistent with these predictions: points of subjective equality (PSEs) were shifted toward slower speeds in the locations where anticorrelated adaptors were presented, and toward faster speeds where correlated adaptors were presented. These patterns of adaptation were evident at a range of speeds and were present regardless of whether adaptor correlation was manipulated between eyes or over time. Our findings thus provide evidence to extend summation/differencing-based efficient coding into the temporal domain and demonstrate the importance of both binocular and temporal efficient coding for motion-in-depth perception. Evidence of adaptation to each of these stimulus types also demonstrates a role for both changing disparity and interocular velocity difference motion-in-depth cues. We consider the implications of these findings for the neural processing of motion-in-depth.

Strategy-induced across-trial variability explains seemingly anti-Bayesian effects in perceived motion

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Motion perception is biased towards slower speeds when sensory noise increases. This classic finding can be explained in Bayesian terms by the increasing influence of a slow-motion prior. Recently, however, Rideaux and Welchman (2020) suggested that increased sensory noise can sometimes be accompanied by no change in bias, challenging both the classic finding and Bayesian interpretation. We replicated this result in three experiments by injecting speed noise into drifting gratings in a standard two-interval speed-matching paradigm. We too found no change in the average point-of-subjective-equality, despite consistently shallower slopes of the psychometric function. Importantly, however, these indices of bias and sensory noise can be misleading when using a speed-noise manipulation. To inject speed noise, positional jitter is added to the stimulus in such a way that the average speed across the whole interval equals the target speed assigned to that interval. However, our analysis revealed that observers did not average over the whole trial but over shorter sections, a strategy that produces a mismatch between the assigned speed and the effective speed driving performance. The latter varies across trials in an uncontrolled fashion, contaminating the psychometric function's slope and point-of-subjective-equality. Using detailed computational modelling, we show that the variability in effective stimulation across trials leads to a shallower slope, incorrectly

suggesting an increase in sensory noise; but it cannot lead to an increased influence of the slow-motion prior within a given interval. Hence the point-of-subjective-equality remains unchanged. Additionally, variability in effective stimulation can induce artifactual biases towards (seemingly) faster or slower perceived speeds. Overall, these findings demonstrate that strategy-induced, across-trial variability corrupts indices of sensory noise and bias, and can account for the seeming anti-Bayesian findings in our experiments and those of Rideaux and Welchman. These results have wider implications for psychophysical testing, computational modelling, and conceptualisations of 'noise'.

The Motion Induced Position Shift on target and cursor items: an optimal control account

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When a moving pattern is presented on a stationary object, the location of the object is misperceived in the direction of pattern motion: the Motion Induced Position Shift (MIPS). Here we used the MIPS illusion as either a moving target or a self-controlled cursor to investigate how visual information is used in continuous target-tracking tasks. In our experiments, the MIPS-object was represented as a limited-life-time random-dot stimulus in which we independently varied the uncertainty in the position of the MIPS-object by changing the size of the dot-cloud, the uncertainty in the pattern motion by varying the distribution of individual dot velocities, and the pattern speed. By looking at tracking errors in the direction of pattern motion we quantified effects of the MIPS for target and cursor objects. Results show that the MIPS effect increased with increased positional uncertainty for target objects but less so for cursor objects; decreased with increased velocity uncertainty; and varied non-linearly with pattern speed. We modelled these outcomes using an optimal control framework (LQG). Our model uses the current system state estimate, consisting of target and cursor positions and velocities and motor control input, to predict the state and expected feedback on the next time-stamp in a feedforward manner. Predictions are then compared to the actual sensory feedback from vision (target and cursor) and proprioception (only cursor) to correct prediction errors in the estimated state. The LQG-model explains our empirical findings by assuming: a) that for the cursor, sensory information from vision and proprioception is integrated in an optimal fashion before this is fed back into the system state; b) uncertainty in the visual velocity is subject to a Weber fraction. In short, the results for our MIPS-continuous-tracking task can be accounted for by a model that combines optimal multisensory integration with optimal control.

Perception of ambiguous multi-component Motion-Clouds varies with image statistics and observers' interpretation of integration-segmentation cues

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We use both Maximum Likelihood Distance Scaling (MLDS) and a Forced Choice (FC) motion component task to study the perception of ambiguous stimuli made of two components moving in the same direction with a range of 11 speed differences. Each briefly presented stimulus can be perceived as coherent, transparent or some intermediate interpretations including shearing or non-rigid. We study how stimulus parameters: spatial frequency, bandwidth and temporal characteristics influence the perceived stimulus differences (MLDS) and reported speed component separation (FC). In the MLDS task, participants were able to perceptually order motion stimuli according to their physical (component speed difference) distance. Moreover, such perceptual ordering is highly dependent on the central frequency and bandwidth properties. Broader bandwidth and higher central frequency components appear more distinct across the range of speed differences tested than the narrow bandwidth and lower frequencies. Lower frequencies tend to show a more abrupt perceptual shift within the speed difference range, so that there is a steep change in perceived difference earlier and a flatter region with higher stimulus similarity later. Participant individual differences are observed in the trends consistent with different perceptual interpretations. The FC task results are distinct in their patterns from the MLDS task: the psychometric curve from the broadest bandwidth condition is steeper on average than for the narrowest bandwidth, and most shallow for the low frequency condition. For complex motion stimuli, MLDS therefore offers an informative window into the segregation and integration of information which depends on frequency content. Richer broadband stimuli seem to afford more options for the perceptual organization of complex moving stimuli than narrowband counterparts. The current findings support the notion that a multidimensional motion processing space is used to disambiguate visual motion stimulation.

Studying Precision and Temporal Dynamics in Heading Perception with Continuous Psychophysics

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It is a well-established finding that more informative optic flow (e.g., faster, denser, or presented in a larger portion of the visual field) yields increased precision in heading judgements. Current models of heading perception further predict faster processing under such circumstances, which has, however, to our knowledge not been shown empirically so far. In this study, we validated a novel paradigm by replicating the effect of the speed and density of optic flow on precision, and we investigated how these manipulations affected the temporal dynamics. To this end, we tested participants in a continuous psychophysics paradigm administered in Virtual Reality. Immersed in a simple virtual environment, they experienced four 90-second blocks of optic flow where their heading direction at any given moment was determined by a random walk. We asked them to continuously indicate with a joystick in which direction they were moving. In each of the four blocks they experienced a different combination of simulated self-motion speeds (SLOW and FAST) and density of objects in the environment (SPARSE and DENSE). Using a Cross-Correlogram Analysis, we determined that more informative optic flow led to faster adjustments and a higher precision in participant responses. Modelling the data using a Kalman filter further showed that perceptual noise was, indeed, higher in conditions with less informative optic flow. Overall, we validated the use of continuous psychophysics for heading perception and further established that more informative optic flow does not only increase precision in heading judgements, but also speeds them up.

Perceptual consequences of neural anisotropies

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Shape-from-motion models generally assume object rigidity, but that disregards the fact that organisms deform non-rigidly for performing many actions. We have shown that horizontal rotation of two rigidly connected circular 3D rings can appear rigid or nonrigid with the rings wobbling and rolling independently, depending on speed and shape. The nonrigid percept arises from populations of motion energy cells signaling motion orthogonal to the contour and is countered by feature-tracking and shape-based priors. Surprisingly, perceived non-rigidity increases if the video is rotated by 90°. At a speed of 6 deg/sec, 4 observers picked vertical rotation as more nonrigid than horizontal on 95% of the comparisons. The vertically rotating rings appear narrower horizontally and longer vertically, so we tested whether the shape misperception explains the increased non-rigidity. To match the shape of each of the physically circular rings, observers stretched the rings in the orthogonally rotated images horizontally (approximately 20-30%). Perceptually matching the shapes reduced the non-rigidity anisotropy by less than 40%, suggesting that motion direction may also play a role. The divergence, curl, and deformation of a velocity field indicate changes in depth, rotation, and slant. We wrote equations for physical rotation combined with physical wobbling (weights k=0-1), and calculated the div, curl and def analytically as a function of the motion phase. The variability of all three gradients increased with the weight of wobbling. We calculated velocity fields for rings that were exclusively rotating horizontally or vertically and then extracted the gradients. The gradients were similar for the two orientations. However, when we matched numbers and tuning widths of motion energy filters to measured V1 anisotropies before calculating velocity fields, the gradients for vertical rotation corresponded closer to physical wobbling (k=0.91) than those for horizontal rotation (k=0.48). Hardwired population anisotropies in V1 thus affect high-level percepts like object non-rigidity.
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Talk Session 2 - Attention

Local and inter-areal communication of auditory prediction error information is selectively modulated by visual attention

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A major question in vision science is how sensory demands in vision can affect global information dynamics in the brain. We present results from 14 patients with intracranial electrodes (stereoelectroencephalography) across their cortical hierarchy. The patients are either attending to auditory stimuli (roving oddball task) or the auditory stimuli is played to them while attending to an unrelated visual attention task. Using information theoretic methods, we investigate how informational dynamics of auditory prediction errors are modulated by visual attention. We compute mutual information (MI) between event related potentials from electrodes from relevant cortical areas (temporal and frontal) and the experimental stimuli (deviant/non-deviant tones). This method differs from standard approaches of network neuroscience. Instead of computing shared information between multiple sites in the brain, we compute the information (in bits) electrodes across the cortical hierarchy encode about the identity of the tones (standard/deviant). We show that local communication of prediction error information is selectively modulated by attention: attending to the visual task increases prediction error encoding in the temporal cortices but reduces encoding in the frontal cortex. Furthermore, by computing co-information, a measure capable of decomposing signals into redundant and synergistic information, we show that information about prediction errors is encoded redundantly and synergistically both within and across cortical areas, and that both types of information are modulated by attention. By employing a brain-constrained neural network to simulate the task, we show that synergistic information in the model only emerges with strong, higher-order forward and backward links. Thus, we present three primary findings: (1) Local and inter-areal communication of prediction error information is selectively modulated by visual attention, (2) This modulation is present in redundant and synergistic information in the brain, and (3) Neurocomputational results: synergistic information encoding in the brain might reflect higher-order forward and backward links between cortical areas.

Dynamic modulations of glutamate with visual attentional load in posterior parietal cortex

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Glutamate is a chief excitatory neurotransmitter in the central nervous system. It is essential for communication between neurons and the basis of brain activity. Despite this importance, it is not yet well understood what role this messenger plays in visual attention in humans. Studies using indirect measures of brain activity such as functional magnetic resonance imaging (fMRI) showed that as visual attentional load increases, the blood-oxygenation-level-dependent (BOLD) response increases in posterior parietal cortex (PPC) but not in early visual cortex (EVC). The question of the research presented here was whether glutamate concentration would be dynamically modulated specifically in PPC with changing visual attentional load in a similar manner to the BOLD response. We used functional magnetic resonance spectroscopy (fMRS) using 3-Tesla MRI to measure the concentration of glutamate in a time-resolved fashion in PPC while participants (n=12) performed a visual multiple object tracking (MOT) task with different levels of attentional load. During MOT participants tracked either two (low load) or four (high load) moving target disks among moving distractor disks. The MOT task was presented using an fMRS-design in which 16s-long trials with low and high load were presented in random order followed by a baseline interval jittered between 8s, 16s, and 24s with central fixation. Glutamate concentration was measured continuously using 2s-long Point RESolved Spectroscopy (PRESS)-scans. In a separate run, fMRS was measured in EVC while participants performed the same MOT task. The results showed increased glutamate concentration in PPC during high compared to low load. No load-dependent modulations of glutamate were found in EVC. This suggests that visual attentional load modulates glutamatergic processing dynamically in PPC and highlights the potential of fMRS to measure task-dependent activity in selected brain regions as an alternative to fMRI.

Attentional guidance through object associations in visual cortex

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Efficient behavior requires the rapid attentional selection of task-relevant objects. Previous research has shown that target-selective neurons in visual cortex increase their baseline firing rate when participants are cued to search for a target object. Such preparatory activity represents a key finding for theories of visual search, as it may reflect a top-down bias that guides spatial attention, favoring processing of target-matching input for subsequent report. However, in daily life, visual search is often guided by non-target objects that are neither externally cued nor reported. For instance, when looking for a pen, we may direct our attention to the office desk where we expect the pen to be. These "anchor objects" (e.g., the desk) thereby guide search for associated objects (e.g., the pen) in scenes. Here, we used fMRI and eye tracking to test whether preparatory activity during visual search represents the target (the pen), the guiding anchor object (the desk) or both. In an anchor-guided search task, participants (N=34) learned associations between targets and anchors and searched for these targets in scenes. To fully dissociate target from anchor processing, target-anchor associations were reversed across different scene contexts. Participants' first fixations were reliably guided towards the target-associated anchor. Importantly, preparatory fMRI activity patterns in lateral occipital cortex (LOC) represented the target-associated anchor rather than the target. Whole-brain analyses additionally identified a region in the right intraparietal sulcus (IPS) that represented the anchor. Our results show that preparatory activity in visual cortex represents a self-generated guiding template, supporting visual search in structured daily-life environments.
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Emergent Neural Signatures of Human-like Covert Attention in Convolutional Neural Networks

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In the last three decades, studies have characterized the mechanisms of visual attention using psychophysics, modeling, and neurophysiology. A common approach has been to experimentally define a manipulation of covert attention using predictive cues (e.g., Posner cueing paradigm) and then study how covert attention alters perceptual performance and neural activity. The modeling has invariably involved investigators explicitly building into the model an attention mechanism (gain change, noise reduction, Bayesian priors, divisive normalization) that modulates information at the "attended location". The attentional benefits and mechanisms are often interpreted in the conceptual framework of limited attentional resources. Here, we take a different approach. We train a convolutional neural network (CNN) to maximize the detection of a tilted line (50 % presence) with a spatially predictive cue and additive noise. The CNN is not trained on human behavioral or primate neural data. We do not explicitly incorporate any attentional mechanism into the CNN that processes the cued location differently. The task-accuracy optimized CNN generates an emergent cueing effect comparable to that observed in humans. Critically, using system neuroscience tools, we characterize the tuning properties of each of 1.8 million CNN neurons to understand how the network integrates the cue, target, and locations to give rise to the cueing effect. The CNN shows emergent neural signatures of covert attention consistent with neurophysiological studies: increasing cue influence with processing across the visual hierarchy, cueing effects emerging after integration across locations, and cue modulation of target neural responses following contrast gain, response gain, and baseline shift. Our analysis also reveals the role of new neuron types not yet reported in neurophysiology: location opponent neurons. Together, the results show that a biologically plausible network optimizing task performance and no limited resource or explicit attention mechanism, results in behavioral and neuronal signatures of human-like covert attention.

Multivariate EEG markers of lapses in visual attention within a dynamic environment

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While crucial for daily tasks, sustaining attention is effortful. Attentional lapses are common and, unfortunately, have the potential to result in fatal consequences (e.g., when driving). In this pre-registered project, we aimed to develop methods to detect multivariate patterns within EEG data indicative of behavioural misses in our Multiple Object Monitoring (MOM) task, which are assumed to result from spontaneous lapses in sustained visual attention. In the MOM task, multiple concurrent moving dots, of either an attended (i.e., task-relevant) or unattended colour, travel along visible trajectories on course to collide with an obstacle at central fixation. On a variable proportion of trials, the dots are automatically deflected away from the collision at a set point in the trajectory. Dots that fail to automatically deflect require a behavioural response by the participant to prevent a collision if they are the attended colour (i.e., targets). We collected EEG data from participants completing this task under an 'active' condition (50% target frequency), in which behavioural performance shows attention can be effectively sustained. We then quantified a proxy measure for how well each dot was encoded during the task from representational dissimilarity matrices characterising the pairwise dissimilarities for 15 discrete distance-from-obstacle bins along the trajectory before the automatic deflection point. This method was successful in decoding the trajectory of each dot from neural data, and showed that the distance-from-obstacle information was stronger for attended dots compared to unattended dots. We further found that when a target was missed, this correlated with a drop in distance-from-obstacle information up to one second before the deflection point, compared to detected targets. Importantly there were no visual differences between hit and missed dots. These results suggest that spontaneous lapses in selective visual attention result in a transient loss of neural information, similar to when stimuli are unattended.
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Characterizing the Interaction of Spontaneous Fluctuations in Sustained Attention and Learned Adjustments in Attentional Flexibility

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Individuals regularly anticipate upcoming demands and adjust their readiness to shift attention, decreasing the cost associated with shifting attention as the shift likelihood increases. However, the extent to which learned fluctuations interact with spontaneous changes in the efficacy of sustained attention remains unknown. Across two studies, we propose and test a model of the interaction between fluctuations in sustained attention and learned attentional flexibility, unifying these two areas of research using behavioral signatures (Experiments 1 and 2), pupillometry (Experiment 1), and functional magnetic resonance imaging (Experiment 2). In this model, the dorsal and ventral attention networks detect violations of- and update predictions for shift readiness, while ongoing changes in default mode network activity account for spontaneous fluctuations in the efficacy of sustained attention and attentional flexibility. Participants completed a variant of the gradual continuous performance task with two side-by-side continuous streams of stimuli. They detected frequent targets among distractors at a to-be-attended stream, made a saccadic eye movement or held attention in response to embedded visual cues, and made a subsequent digit categorization as a measure of shift readiness. We manipulated the frequency of shift cues and observed modulations of shift costs and saccade latencies as evidence of learned attentional flexibility. Periods of poor sustained attention, as derived from trial-by-trial target detection response time variability, were associated with above and below average pupil sizes, consistent with models of arousal, and with larger learned modulations of attentional flexibility. This indicates that trial history plays a larger role in updating shift readiness when the focus of sustained attention is poor. Brain activity within the dorsal and ventral attention networks scaled with shift readiness prediction errors and this association was distinct from sources of spontaneous changes in shifting readiness. Together, our results provide a unified account of within subject variation in attentional control.
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Talk Session 3 - Social Perception

Abstraction of Mind in Pictures and the Medusa Effect

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Throughout history, humans have favoured depicting things with minds in pictures. We report that abstraction in pictures diminishes perceived mind, a phenomenon called the Medusa effect. Specifically, people appear more real and higher in Agency and Experience when presented directly as pictures rather than as pictures of pictures. As mind perception underpins moral judgement, depicted persons may receive greater or lesser ethical consideration, depending on the level of abstraction. Consistent with this, we show that viewers are less generous towards more abstracted individuals. Finally, we report individual differences in the Medusa effect, as well as an ability to control it both qualitatively and quantitatively.
Acknowledgements: NSERC.

Converging evidence that left extrastriate body area supports visual sensitivity to social interactions

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Navigating our complex social world requires quickly identifying and processing the interactions we observe. Recent psychophysical and neuroimaging studies provide parallel evidence that the human visual system may be attuned to efficiently perceive dyadic interactions. This work implies, but has not yet demonstrated, that activity in body-selective cortical regions causally supports efficient visual perception of social interactions. We adopt a multi-method approach to close this important gap. First, using a large fMRI dataset (N=92), we found that the left-hemisphere Extrastriate Body Area (EBA) responds more to face-to-face than non-facing dyads. Second, we replicated a behavioural marker of visual sensitivity to interactions: the categorisation of facing dyads is more impaired by inversion than it is for non-facing dyads. Third, in a pre-registered experiment, we used fMRI-guided transcranial magnetic stimulation (TMS) to show that online stimulation of the left EBA, but not a nearby control region, abolishes this selective inversion effect. This work demonstrates that activity in left EBA, thus, causally supports the efficient perception of social interactions.
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Uncanny valley for dynamic bodies in nonhuman primates

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Virtual agents and robots that are very similar to humans often cause aversive emotional reactions, compared to prefer perfectly realistic and unrealistic agents. This effect is called the uncanny valley (Mori, Energy, 1970). An uncanny valley has also been described for faces, and more recently also for the static and dynamic face perception of non-human primates (Steckenfinger et al., PNAS, 2009; Siebert et al., eNeuro, 2020). Whether monkeys show an uncanny valley effect for bodies is unknown. METHODS: Classical motion-capture animation is not applicable for monkeys since they do not tolerate reflecting markers on their bodies. Popular video-based tracking methods (such as DeepLabCut) are not accurate enough for 3D computer animation, or require too much hand-labelling. We developed a multi-camera video-based tracking approach that produces accurate tracking data at high frame rates, requiring hand labelling of only 2 frames per second. We animated a commercial monkey avatar and created degraded versions of it and compared these stimuli to real videos of the same actions. Fixation behavior of 8 monkey observers was quantified. RESULTS: We found a significant uncanny valley for body perception. In addition, the fixation behavior of the animals did not differ significantly between the real video and the non-degraded avatar. CONCLUSIONS: As humans, monkeys show an uncanny valley also for dynamic bodies. This supports the homology of the underlying processing mechanisms. In addition, our methods generate avatars that are perceived as fully realistic by macaque monkeys.

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A visual search advantage for communicative interactions over independent actions

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There is evidence that the human visual system processes interacting agents as a unified whole, rather than each agent independently, to infer social interactions. For example, in visual search paradigms, there is a search advantage for face or body pairs that face each other compared to those that face away or in the same direction. In these studies, facing direction serves as a proxy for interaction, but evidence of a search advantage for actual (dynamic) interactions is currently lacking. We therefore used a visual search paradigm to test whether people are better able to find communicative interactions between agents in a crowd. Participants viewed arrays of point-light dyads and searched for an interacting dyad amongst a set of non-interacting dyads, or for a non-interacting dyad amongst a set of interacting dyads, with targets present on half the trials. Interacting dyads displayed communicative gestures between the two agents. In Experiment 1, participants were faster and more accurate to detect the presence of interacting than non-interacting target dyads. They were also more efficient searching for interacting targets, as reflected by shallower search slopes. These findings were replicated in Experiment 2, where we also used eye tracking. Participants made more and longer fixations for target compared to distractor dyads, regardless of whether the targets were interacting or not. The findings suggest that spatio-temporal contingencies between agents during communicative interactions can lead to more holistic processing and facilitate visual search. However, participants did not need to fixate overtly on the agents for this visual search advantage from these contingencies. Future studies that manipulate communicative interactions and non-interacting dyads (e.g., facing direction) can help relate fixation patterns to visual search performance.

Dissociation between Social and Visual Information in Dynamic Social Interaction Processing

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When processing perceptual information, individuals are influenced by past experiences, leading to attraction or repulsion towards previous information. However, it remains unclear how past experiences impact the processing of complex social interaction perception, which includes various visual cues like distance and facing orientation of two persons. This study aims to discern the roles of social information and visual cues in dynamic social interaction processing. Participants observed two avatars displayed on the screen at different distances and facing orientations and performed either a social interaction judgment task (judging whether the avatars were interacting) or a distance judgement task (whether the distance between them was exceeded a standard distance). The prior and test stimuli were alternately presented, where the prior provided definite interaction or distance judgments, while the test introduced strong uncertainty in both tasks. The results revealed that past social interaction states exert an attractive effect on current interaction perception. Participants were more inclined to perceive interaction in the test stimuli when the prior stimuli were interactive compared to non-interactive (61.3%±3.2% vs. 55.8%±3.1%, $p = 0.039$). This attractive effect only evident when the prior involves interaction rather than distance judgment task ($p = 0.514$). On the contrary, past visual cues exhibit a repulsive effect on current interaction perception. Participants were more likely to perceive interaction in the test stimuli when adapted to pairs of avatars with larger facing angle (more similar to non-interactive) compared to non-adapted baseline (70.5%±4.0% vs. 60.8%±3.8%, $p = 0.011$). These findings highlight a distinct mechanism underlying the integration of past social and visual information, whereby current social interaction representation tends to be biased toward past interaction states, but being influenced by visual cue representations that may deviate from past visual cues. This extends the temporal mechanism of generative perceptions from sensory perception to social information processing.

Evidence of a third functional visual pathway

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The idea the human brain has two visual pathways, one ventral, one dorsal, is widely accepted. However, at least three groups have independently suggested there is a third visual pathway. The hypothesised third pathway has variously been proposed to be a division of the dorsal pathway; a pathway specialised for fast motion processing; or a pathway specialised for social perception. A standard technique to identify brain networks is to collect measurements of brain activity (BOLD) in an MRI scanner data while the observer is at rest (typically looking at a fixation point against a blank screen) and then fractionate the brain into networks by performing Independent Components Analysis (ICA) with a dimensionality (20-30) on the data. This technique separates out dorsal and ventral network components, but conspicuously provides no evidence of a third pathway. We investigated whether a third functional visual network would be revealed when the brain was in a natural state, actively processing naturalistic visual stimuli. 21 observers watched a ~20min clip from a Hollywood action movie. We performed ICA on the data and found an additional visual network component segmented off from the dorsal network component. It was a lateral component that included the motion processing complex (MT+/V5) and extended into the superior temporal sulcus (STS). We replicated the finding with an independent dataset, the public domain, HBN-SSI. Usefully the HBN-SSI dataset included not only data collected during rest and data collected when watching Hollywood movies, but also data from observers watching abstract geometric animations ("Inscapes"). The Inscapes dataset resembled the resting state data, a lateral component was not present. The location of the lateral pathway, and its disappearance when viewing the inscapes animations, is most compatible with the proposal of a third lateral visual pathway specialised for social perception.
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Talk Session 4 - Clinical Vision

Decreased scene-selective activity within the posterior intraparietal cortex in amblyopic human adults

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Introduction: Amblyopia (lazy eye) is a developmental disorder associated with reduced performance in visually guided tasks, including navigation within natural environments, even with binocular viewing. Currently, our understanding of amblyopia impacts on higher-level visual areas, especially those that are selectively involved in navigation within scenes, remains very limited. To fill this gap, we used functional MRI (fMRI; 3T), to study the amblyopia impact on the functional organization of scene-selective cortical areas, including the posterior intraparietal gyrus scene-selective (PIGS) area, a newly discovered region that responds selectively to ego-motion within naturalistic environments (Kennedy et al., 2024). Methods: Eighteen amblyopic adults (11 female; 18-56 years old) and twenty-four age-matched controls (12 female; 22-40 years old) participated in this experiment. The amblyopic participants (8 strabismic, 9 anisometropic, and 1 deprivational) spanned a wide range of amblyopia severity, based on the interocular visual acuity difference (0.02 – 1.08 LogMAR) and stereoacuity (40 to >400 arcsec). During the scans, participants were presented with binocular, non-stereoscopic images of natural scenes, faces, and intact/scrambled objects. Results: Compared to controls, the size of the PIGS was reduced significantly in amblyopic individuals ($p=0.01$; corrected for multiple comparisons). This effect was associated with a weaker scene-selective activity within PIGS ($p<0.01$). Both effects were detectable in strabismic and anisometropic individuals without any apparent difference. In comparison, the size of the occipital place area (OPA), parahippocampal place area (PPA), and retrosplenial cortex (RSC), as well as the level of scene-selective activity within them remained comparable between amblyopic and control participants ($p>0.10$). Moreover, the level of activity evoked within V1, V6, and LOC remained comparable between the two groups ($p>0.10$). Conclusion: These results provide novel and direct evidence for amblyopia-related changes in scene-processing networks, preparing a foundation for future studies to potentially link these changes across the spectrum of documented disabilities in amblyopia.

The perceptual characteristics of phosphenes induced via intracortical electrical stimulation of the visual cortex

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Electrical stimulation of different areas in the visual hierarchy induces ‘phosphenes’, small dots of light, which can be used as building blocks to provide prosthetic vision to the visually impaired. To explore the potential of intracortical electrical stimulation as an interface for visual neuroprosthesis, we implanted a Utah Array consisting of 96 penetrating electrodes into the early visual cortex of four blind human volunteers. In this study, we focus on the perceptual characteristics of the phosphenes; information which is particularly difficult to acquire from non-human subjects. In different experiments, the participants were asked to describe, draw, discriminate or rate their subjective perception of phosphenes stimulated via single or multiple electrodes in varying parameters. We recorded the shape, size, brightness, colour and duration of phosphenes. We found that the phosphene shapes induced by both single and multiple electrodes varied from a single dot to complex shapes in different sizes. The stimulation via a combination of electrodes resulted in phosphene shapes different from the additive of the single electrodes. Additionally, one of the volunteers perceived phosphenes in different colours, including white, yellow, green and orange. Higher brightness and larger size phosphenes were generally induced by stimulation parameters inserting more charge. The duration of a single stimulation train was perceived as a brief phosphene by three of the volunteers; however, much longer phosphenes were perceived in response to a single stimulation in one of the participants. Our findings show that intracortical electrical stimulation administered to the early visual cortex can elicit phosphenes which exhibit varying appearances among individuals. These differences may stem from slight variations in the implantation site, the underlying cause of vision loss, or the duration of blindness experienced by each individual. Further investigation is needed to understand and guide the stimulation methods that lead to the most appropriate subjective perceptions.
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Altered Perception of the Bistable Motion Quartet in Albinism

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The motion quartet (MQ) consists of two alternatively appearing and disappearing pairs of dots located on the diagonal corners of an imaginary rectangle. It is perceived as two dots moving either horizontally or vertically as a function of the ratio between horizontal and vertical dot distances (aspect ratio, “AR”). At AR = 1 perception should be ambiguous, but the literature indicates a strong vertical bias. Typical explanations postulate easier motion processing within brain hemispheres (vertical motion perception) compared to a necessary interplay between the hemispheres (horizontal motion perception). Persons with albinism (PWA) have an abnormally large number of crossing neurons at the optic chiasm. As a consequence, a larger part of the right and left visual hemifields are represented on both brain hemispheres. This should result in a significantly reduced MQ vertical bias in PWA, which we investigated in the present study. 14 PWA, 12 participants with nystagmus, but normal optic chiasm (PWN) and 11 healthy controls (HC) observed ambiguous MQ stimuli and reported the direction of perceived motion. We varied the AR between 0.75 and 1.25 and compared vertical motion percept probabilities as a function of AR between groups. For HC, the vertical motion percept probability increased as a sigmoid function of increasing AR with a strong vertical motion percept bias. In contrast, PWA showed the opposite, i.e. a surprisingly strong horizontal bias independent of the AR. The PWN were in between PWA and HC. The strong horizontal bias observed in PWA and PWN might partly result from the horizontal nystagmus. The even stronger horizontal bias in PWA compared to PWN, given comparable fixation instabilities, indicates an additional role of the intra-hemispherical co-representation of both visual hemifields. Our findings open opportunities to better understand altered visual pathway conditions and to identify them with a perception-based test using the MQ.
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Objectively Measuring Sight Rescue in Severely Vision-Impaired Young Children Following Gene Therapy

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Recent breakthroughs in ocular gene therapy hold significant promise for treating inherited retinal diseases (IRDs), the prevalent cause of blindness in children and young people. IRDs compromise the retina's structure and function, with severe forms leading to complete loss of light sensitivity in early childhood. However, significant challenges remain in objectively characterising the effects of new therapies, particularly for very young children. Vision-impaired toddlers and children typically struggle to keep their gaze focused on visual stimuli or provide consistent responses, and traditional assessments typically are heavily reliant on subjective evaluations by highly trained clinical specialists. To develop objective measures of therapeutic effects complementing existing assessment, we used child-friendly neuroimaging and gamified testing approaches. Using steady-state visual evoked potentials (ssVEP) measured with EEG, we non-invasively recorded cortical responses to flickering sinusoidal gratings with varying spatial frequencies. To ensure engagement we integrated gratings within personalised age-appropriate videos. Additionally, we used a novel reaching-behaviour test embedded in a child-friendly iPad game that involved searching and tapping moving Gabor patches of varying spatial frequencies. Applying these protocols, we obtained objective measures of visual sensitivity in two young children with Leber Congenital Amaurosis aged 5 and 6 years who had received gene therapy 3 years prior. As both children were treated in only one eye, the remaining eye provided a within-subject comparison. In both children, our tasks revealed substantially stronger visual cortex responses and better behavioural task performance for the treated than the untreated eye. The improvements observed are remarkable, especially when considering the typical progression of the disease and the benefits of available ocular gene therapies. This is likely facilitated by the exceptionally early time of intervention, minimising retinal degeneration and maximising neural plasticity. Establishing sensitive, child-friendly and objective measures for evaluating early treatment effects is critical for advancing the field of ocular therapy.

Changes in primary visual and auditory cortex of blind and sighted adults following echolocation training

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Recent work suggests that the adult human brain is very adaptable when it comes to sensory processing. In this context it has also been suggested that structural 'blueprints' may fundamentally constrain neuroplastic change, e.g. in response to sensory deprivation. Here, we trained 12 blind participants (BPs) and 14 sighted participants (SPs) in echolocation over a 10-week period, and used MRI in a pre-post design to measure functional and structural brain changes. We found that BPs and SPs together showed a training-induced increase in activation in left and right V1 in response to echoes. BPs and SPs also showed a training induced increase in activation in right A1 in response to sounds per se (i.e. not echo-specific), and this was accompanied by an increase in grey matter density in right A1 in BPs and in adjacent acoustic areas in SPs. These findings are difficult to reconcile with the view that sensory cortex is organised by modality, as both sighted and blind participants showed increased echo-acoustic related activity in V1 in response to echolocation training. The similarity in results between SPs and BPs is also consistent with the idea that reorganization may be governed by similar principles in the two groups.

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Unanticipated Brain Reorganization Mechanism in Blind Spatial Navigation Learning

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The visual motion complex (hMT+) has shown unexpected versatility in tasks beyond motion perception. We investigated this extended functionality and its reorganization through learning in blind individuals using the rapid Cognitive-Kinesthetic Memory-Drawing Training (initially developed for the manual domain by Likova), which was translated to the full-scale navigation domain. Methods: Blind participants underwent the Cognitive-Kinesthetic Memory-Drawing Training using tactile maps. Pre- and post-training whole-brain scans were conducted with a Siemens 3T Prisma scanner. Participants haptically explored and memorized maps with one hand (30 s); after 20 s rest, they drew the maps from memory with the opposite hand (30 s). Results: Despite the absence of vision and visual motion, hMT+ was activated by both non-visual tasks, moreover, revealing significant interhemispheric functional asymmetry. The left-hand haptic-memory encoding task exclusively engaged the right-hemisphere hMT+, while the right-hand map-drawing from haptic memory task activated hMT+ bilaterally. Post-training analyses unveiled a previously unknown type of massive brain reorganization in the blind, forming large clusters around hMT+ with consistent left/right asymmetry. Thus, neighboring visual areas with well-known functional distinctions in the sighted, were reshaped into large functionally-unified clusters in the blind. Granger Causal connectivity analysis comparatively examined the pre/post-training network organization of the newly formed cluster's ROIs, motor, somatosensory, and memory areas. Conclusions: The findings of this study on spatial navigation significantly enhance our knowledge of non-visual functionality of hMT+ and have profound implications for understanding the functional architecture of spatial navigation and principles of brain reorganization through learning.

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Poster Session 2

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Investigating the mechanisms of global confidence

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Global confidence plays a crucial role in decision-making processes by enabling individuals to assess their overall task performance. The calibration of global confidence is essential, as miscalibration could lead to misjudgments of one's skills and abilities and affect larger-scale decisions. The present study sought to understand the formation of global confidence from finer-level local confidence through two experiments. In Experiment 1, participants were tasked with deciding which of two presented boxes contained more dots and rated their (local) confidence of being correct for each trial. At the end of each short block, participants were asked to assess their confidence in their performance across the entire block (global confidence). Some trials were made memorable by presenting a memorable image before the perceptual stimulus, while other trials were tagged with forgettable images in the same way. No significant difference was found in how local confidence contributed to global confidence between memorable and forgettable trials. However, we considered it possible that manipulations of memorability more proximal to the local confidence assessment may have a greater effect. Experiment 2 sought to address this hypothesis by directly manipulating the local confidence reporting phase. Participants were informed that certain trials carried the potential for a bonus based on their performance, with this information revealed only after reporting local confidence. Results indicated that the meta-metacognitive sensitivity - the ability to relate global confidence to local confidence - was more disrupted in blocks containing these special trials, as if these trials inserted more noise in the global confidence formation process. Additionally, both experiments revealed a recency effect in the formation of global confidence from local confidence judgments. These findings shed light on the dynamics underlying how global metacognition is informed by local confidence and emphasises the importance of further exploration in understanding how individuals calibrate their metacognitive judgments.

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The impact of rotation on shape recognition is dependent on curvature features

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The human visual system is exposed to a vast number of objects. Each of these objects can create an infinite number of 2-D images on the retina, because the object's size, rotation, perspective, etc. vary relative to the observer. Yet, human object recognition is largely independent for a wide range of naturally occurring transformations. This invariance of object recognition continues to be a challenge for some shape transformations in computer vision. For instance, methods like convolutional neural networks can be invariant to scale and translation but not to rotation. We previously investigated the role of shape curvature features, i.e. convexities and concavities in shape recognition for a variety of curvilinear planar shapes with well-defined convexities, concavities, and intermediate regions, segmented to isolate each feature type. Observers had to match a segmented reference shape to one of two subsequently presented re-scaled and re-positioned whole-contour shapes (target and distractor). Results showed that for dot-sized segments, performance was significantly higher for convexities compared to concavities and intermediate points, and independent of segment length. Convex curvature maxima contained sufficient information to match it to a whole-contour shape. In the current study, we employed the same paradigm and stimuli, but the influence of rotation was tested by applying rotation angles (±5˚ - 90˚) to the target shape. Results show that for convexities, performance decreased with increasing rotation angle, but reached chance level for rotation angles of ~30˚. Performance was independent of segment length. For concavities and intermediate segments, however, subjects performed at chance level for all segment lengths, except when the reference shape was an unsegmented (continuous) shape. These results suggest that points of convex curvature maxima are critical features for recognizing this class of planar shapes.

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Watch your step: Similar gaze behavior during perturbed walking in younger and older adults

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Gaze behavior during active locomotion allows us to adjust the gathering of visual information to situational and personal needs. For instance, when walking over difficult terrain, by directing our gaze more frequently to the ground, we prioritize gait-related information to prevent falling. Here we focus on the question whether such prioritization changes over the adult lifespan. 24 older (60-80 years) and 24 younger (20-40 years) participants walked on a split-belt treadmill along a path in a virtual-reality landscape projected to a 240-degrees screen. In a condition mimicking difficult terrain, the left or right belt of the treadmill occasionally accelerated during a single step resulting in a backward slip of the foot as if slipping on ice. Such gait perturbations could be accompanied by a visual cue (an approaching virtual patch of ice on the path), allowing for its anticipation. In another condition, the gait perturbations occurred at unexpected times without a visual cue. We further included blocks of unperturbed walking as control. Eye tracking and motion capturing were used to extract participants' gait kinematics, head and eye movements, as well as their pupil diameter. During unperturbed walking, we find differences in gait parameters between the age groups indicating a reduction of gait stability in the older participants. Median gaze orientation and the fraction of time points during which gaze is allocated to the ground do not differ significantly between age groups. In response to gait perturbations, gaze orientation was lowered, pupils dilated, and gait was adjusted. These effects occurred anticipatorily when visual cues announced a perturbation. Perturbation effects on gaze parameters and on gait kinematics were largely similar in both age groups. Thus, we conclude that gaze behavior is dynamically adjusted to situational demands and that such adaptive processes, at least in our setting, are robust during healthy ageing.
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Attentional shifts involving objects - insights from pupillometry and individual differences in internal noise

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Object-based attention (OBA) refers to the enhanced processing of information within an attended object. Previous studies have shown that OBA leads to relatively small and inconsistent effects compared to space-based attention—the enhanced processing of information presented at a cued location. Additionally, the orientation of the attended object or whether attention is required to cross the horizontal or vertical meridian seems to influence the size of OBA effects. Here, we focused on inter-individual differences and used various methods to better understand the low consistency in OBA effects. We estimated individual levels of internal noise from trial-to-trial variability in a double-pass procedure combined with an external noise paradigm and computational modeling. With the two-object paradigm of OBA, the participant's level of internal noise predicted the magnitude of their attentional-shifting cost when attention shifted horizontally but not for vertical shifts – regardless of object orientation. Additionally, participants with low internal noise levels displayed significant object-based effects only with horizontal objects. Evidence from attentional modulation of the pupillary light response (PLR) provided further insights about attentional shifts involving objects. Using a single-object paradigm, we tested attentional shifts from a location outside an object to a location inside an object or vice-versa. When the object was oriented vertically and shifts of attention were horizontal, the PLR provided evidence that shifts requiring disengagement from an object were slower than those that did not involve such disengagement. Interestingly, however, when a horizontal object was employed and the task required attention to shift vertically, no evidence of attentional shifting emerged from the PLR, regardless of disengagement type. Taken together, these findings suggest that the high variability and low reliability of OBA effects can be at least partially explained by low-level factors such as the level of internal noise or the direction of attentional shifts.
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Spatio-temporal interactions in visual crowding

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Crowding, where perception of a target is impaired due to the presence of nearby flankers, is mostly treated as a spatial phenomenon. According to a common view, target information is irretrievably lost at early stages of visual processing, hence, temporal aspects cannot be of any relevance. Here, we show that crowding can be modulated for durations of up to 1 second. Participants discriminated the left/right offset of a vernier flanked by lines or cubes, all presented for 20 ms. Crowding was strong in both flanker conditions. When a quick preview of the cubes and lines was given for 20 ms, crowding decreased for the flanking cubes but not for the flanking lines. The same release of crowding did not occur when the flankers were shown after the display with the vernier and flankers (postview condition). We argue that grouping across time plays a crucial role: when the flankers can be grouped away from the target, performance improves. Our preview effect is robust and long lasting: crowding is weakened for ISIs of up to one second, pointing to massive recurrent interactions taking place. The release of crowding persists also when additional flankers are shown during the ISI, but only when the elements are consistent with the grouping cues of the cuboids. Our results are predicted by the Laminart model, in which objects in the scene are segmented in different layers through feedback connections. Crowding is weak when the flankers are segregated away from the target. When this segregation cannot happen, we observe strong crowding. Giving a preview of the cubes provides the model with sufficient time to isolate the target in a distinct layer from the flankers. Overall, our results highlight the fundamental role of grouping mechanisms in spatio-temporal vision.

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Exploring the impact of image region importance for pleasure and interest on art image inspection

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When inspecting an artwork, one is often struck by details that invite further exploration. Some image regions contain more of these details than others. To study their impact on perception and aesthetic appreciation, we define 'details' quite broadly as all possible image inhomogeneities and acknowledge that they can differ widely in terms of size and importance. These image regions can therefore be thought of as potential aesthetic hotspots. In the present study, we investigate whether viewers inspect these inhomogeneities more frequently or for longer durations compared to other image regions. To address this question, we have developed image aesthetic maps by mapping the importance of local image regions back onto the image across the whole image. In the first experiment, we generated image aesthetic maps for images of paintings and artistic photographs selected based on a previous validation study. The images were first decomposed into rectangular-shaped local image patches, which were then rated by a large pool of online participants on their importance for the pleasure of, and interest in, the whole image. After a series of pooling, averaging, and smoothing steps, these ratings provide the spatial distribution of the local aesthetic importance ratings for that image. In the second experiment, we recorded eye movements to investigate whether the local aesthetic importance of an image region is predictive of visual attention to that image region. In particular, we investigated the contribution of local aesthetic importance in predicting visual attention to images beyond their low-level salience. Additionally, we investigated the relative contributions of pleasure and interest ratings in predicting visual attention to image regions over time using a time-window analysis. We will present the results of both experiments and consider implications for the role of local pleasure and interest ratings in the visual inspection of global images.
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Approach and retreat: Dynamically adjusting distance for size judgments in VR

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In everyday life we continuously make simple visual judgements about object properties (e.g. how big or wide is an object?). Such judgments have been tested extensively in psychophysics when viewing objects on a computer screen at a fixed distance. However, in the real world, we have an additional degree of freedom: approaching an object enlarges its retinal size, while retreating diminishes it. Our goal is to test how observers dynamically adjust their position relative to the object to optimize size judgements for both large and small objects. Observers viewed scenes with two rectangular prisms presented in a photorealistic virtual reality environment, starting either 1 meter or 3 meters away from the object. They were instructed to adjust their position until the width difference between both objects was most noticeable, and to select which of the two objects was wider. Each scene contained a standard object with a width of 1m, 0.5m, or 0.15m, alongside a comparison object whose width was presented at the same size or 5% or 10% larger or smaller. For near starting points observers tended to move backwards prior to the width judgement, particularly for larger objects. Observers tended to move forward for smaller objects, particularly for the far starting point. Therefore, the size of the standard object at the end of the trial was more similar for both the near and far starting points, but it still varied systematically with object size; larger for the large objects, and smaller for the small objects. As opposed to following the simple strategy of selecting a distance that makes all objects the same retinal size, observers instead show a preferred size that varies with the object size tested. This effect was robust, regardless of the size difference between the standard and test object.
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The spatial-frequency selectivity in cyclopean vision may arise from the processing in the extrastriate cortex

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Previous studies have demonstrated the existence of multiple cyclopean spatial-frequency channels tuned to the spatial frequency of sinusoidal corrugations (gratings in depth). Cyclopean masking experiments with narrowband noises, have shown that the disparity thresholds, as a function of the mask's central spatial-frequency, have a band-pass shape, reflecting a band-pass selectivity of the stereoscopic channels. One open question is the location of the physiological counterpart to these channels. The primary visual cortex would be a good candidate, as in luminance channels. However, these masking results would be hard to reconcile with the known low-pass response of V1 neurons to sinusoidal corrugations of different spatial frequencies. Here, we test this by conducting cyclopean masking experiments and fitting the output of a spatiotemporal local cross-correlation model that approximates the disparity-energy calculation in V1. Using dynamic random dot stereograms, we measure disparity thresholds for vertical and horizontal sinusoidal corrugations with spatial frequency of 0.2c/deg masked by narrowband noises centered in five spatial frequencies (0.05, 0.1, 0.2, 0.4, & 0.8c/deg) and with three different noise power levels. Disparity thresholds, as a function of the mask center spatial-frequency, show a band-pass shape with the maximum at the spatial frequency of the signal for both orientations and for the three noise levels. To obtain the disparity thresholds from the model, we used the same stimuli as those used in the experiments. Fitted disparity thresholds from the model as a function of the mask center spatial-frequency exhibit a low-pass shape for both orientations and three noise levels. Consequently, this model, consistent with the physiology of the primary visual cortex, fails to account for the diminished impact of noises centered on spatial frequencies lower than that of the signal. Therefore, the band-pass masking shape or the stereoscopic channel selectivity, is probably caused by the processing in the extrastriate cortex.
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Budget-friendly commercial OLED displays for vision science experiments

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Many experiments in vision science require precise control over the physical, colorimetric and photometric properties of presented light. Most commercial display panels are not made to meet these requirements, for example, due to device-internal firmware that can silently alter the requested display values in highly nonlinear ways. Liquid Crystal Displays (LCDs) have well-known drawbacks, particularly regarding their slow temporal response and poor contrast. Organic Light-Emitting Diode (OLED) displays in theory have excellent temporal and spatial properties, but previously measured devices showed various undesirable behaviours. Here we evaluate two recent commercial OLED devices: an ASUS ROG PG27AQDM gaming monitor, with a native resolution of 2560 by 1440 pixels with 10 bits per channel at 240 Hz, and a SAMSUNG GQ65S93CAT OLED 4K TV 3840 by 2160 with 10 bits per channel at 120 Hz, and compare them to the VPIXX PROPIXX projector system (VPIXX Technologies Inc.) 1920 by 1080 with 12 bits per channel at 120 Hz. We measure luminance uniformity, luminance linearity, channel independence and additivity, contrast ratios (on/off and simultaneous), colour accuracy, response time and temporal stability. In general, both commercial monitors perform better than we initially expected. For example, the ASUS monitor shows a very nice additivity property when compared to the reproduction of the grayscale, whereas the SAMSUNG exhibits a noticeable non-linearity and strong non-additivity in which the luminance sum of the separate channels RGB tends to overshoot when compared to the grayscale curve. Overall, the ASUS OLED with careful setup performs comparably with the PROPIXX system for most of the tests. These results provide a positive outlook: some commercial OLED devices appear suitable and budget-friendly for many precision-critical perception experiments. However, specific monitor settings critically influence display behaviour: careful calibration is still strongly recommended.

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Compact Aerial Display With Scrolling Display in Two Directions by Using Slanted Slit-Shaped Retro-Reflector

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Digital signage using LED has become the most popular digital signage in a variety of applications. In recent years, signage using aerial display technology in an empty space has been attracting attention. One of these aerial imaging technologies is aerial imaging by retro-reflector (AIRR). AIRR is characterized by no need of special glasses, its high flexibility in its configuration, especially in enlargement. However, larger the image size, more unnecessary space is required because of large diagonal beam splitters. Our previous study has proposed the compact aerial display with a vertical slit-shaped retro-reflector in front of the light source, which reduces the unnecessary space. Although this compact aerial display has a problem of image gaps by of slit-shaped retro-reflector, this problem can be solved by subjective complementation using scrolling image. However, this compact aerial display has a limitation in scrolling direction, resulting in a low content flexibility. In this study, we propose a compact aerial display with the slanted slit-shaped retro-reflector. In the experiment, the slit angles of retro-reflector in front of the light source were 0 (horizontal), 15, 45, 75 and 90 (vertical) degrees and image scrolling direction were vertical and horizontal. When the slit angle is 0 degrees (horizontal), subjective image complementation only works in the vertical scrolling direction, and when the slit angle is 90 degrees (vertical), subjective image complementation only works in the horizontal scrolling direction. On the other hand, when the slit angle is 15, 45, or 75 degrees, subjective image complement works in both directions, and the entire aerial image can be seen.Thus, slanted slit-shaped retro-reflector can subjectively complement i mage gaps of retro-reflector not only in the horizontal scrolling but also in the vertical scrolling, resulting a compact aerial display with a high flexibility in the contents.

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Shopping with vision loss: Using VR to quantify the impact of simulated visual field defects

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Purpose: To quantify the relative impact of scotoma size and eccentricity on vision-related quality of life. Methods: Normally sighted subjects (n=19; additional data collection ongoing) were asked to locate household products in a virtual reality supermarket. Participants were able to physically move around the supermarket (body-tracking), using their hands to pick up prespecified items from shelves and deposit them into a virtual trolley. The open-source “VARID” toolkit (varid.co.uk) was used to generate gaze-contingent scotomas of variable size and eccentricity. Each participant experienced five of nine bilateral scotomas, varying in eccentricity (1° – 9°) and/or radius (1° - 9°). Outcome measures included task-completion times; quantities of head, eye, and body movements; and numbers of errors (e.g., number of items knocked over). Results: Participants spent longer searching for items in the presence of a 9° radius scotoma at 9° eccentricity, versus no impairment (mean {95%CI} increase vs. no impairment = 66 {12 – 120} seconds, P=.023). The effect was largely unchanged when participants experienced a 6° radius scotoma at 6° eccentricity (mean {95%CI} increase vs. no impairment = 58 {31 – 86} seconds, P<.001), and was reduced by only 35% when participants experienced a 1° radius scotoma at 1° eccentricity (mean {95%CI} increase vs. no impairment = 38 {4 – 72} seconds, P=.029). Further analyses are ongoing and shall also be reported. Conclusion: The eccentricity of a scotoma, and specifically whether it impinges upon the point of fixation, greatly impacts performance on the present visually guided “real world” search task, more so than the absolute size of the scotoma. More generally, this work demonstrates the potential of immersive, interactive virtual reality environments to objectively quantify vision-related quality of life. Details of the virtual reality environment and simulated scotomas, including how to obtain them, shall also be presented.
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Changing Tracks: How visual presentations of travel itineraries impact the choice between plane and train

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Recognizing the negative environmental impact of air travel highlights the pressing need to reconsider our travel preferences, particularly in scenarios where viable alternatives exist. Every air traveler knows that the total travel time includes more than just the flight time. However, when comparing transport modes (e.g., airplane vs. train) for a journey, these additional times—for security checks and baggage claims—are neglected, leading to an inflated perception of time savings through flying, thus making it seem a more attractive choice than it should be. The question is whether a visualization of the entire travel duration in the form of a comprehensive itinerary at the time of the decision can correct this bias and increase the likelihood of people choosing the train. A first randomized online study (N = 608) showed that a comprehensive travel itinerary increased the likelihood of choosing the train from 66% to 79% compared to a standard itinerary; this result is probably because the visualization emphasized the convenience of traveling by train. The follow-up study (N = 383) examined how various factors—different travel distances, price scenarios and comfort levels (train routes with up to three transfers)—impact the above-observed effect. We found that a comprehensive itinerary consistently increased train preference by an average of 15%, even when flights saved over three hours, across different price conditions, and regardless of train route convenience. Our study demonstrates the effectiveness of a simple visual nudge in encouraging sustainable travel choices, suggesting avenues for future research to explore how these strategies can enhance decision-making across domains like health and sustainability.

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Unraveling the Coordination of Perceptually Relevant Alpha Oscillations: a Large-Scale Network Synchronization study

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Background: Recent findings indicate the existence of multiple perceptually relevant posterior alpha oscillations within the canonical alpha-band (8-14Hz) that can be dissociated across time, frequencies, and anatomical domains. We hypothesize that changes in different alpha sub-bands are associated with independent but coordinated mechanisms that facilitate attention and perception processing. However, how these alpha-sub-band amplitude changes across frequencies and brain regions are coordinated remains unexplored. Aim: We investigate whether large-scale network synchronization acts as a mechanism for coordinating attention-related modulations of alpha-band amplitudes and behavior across alpha-sub-band frequencies and brain regions. Methods: MEG/EEG data were concurrently recorded from 32 participants during covert visuo-spatial attention shifts (spatial cue) and two control conditions (neutral cue, no-attention cue), while fixational eye movements were tracked. Data was reconstructed and collapsed into 200 parcel time series. Inter-parcel phase synchrony was evaluated using weighed Phase Lag Index (wPLI) and imaginary Phase Locking Value (iPLV). Results: Our data-driven analysis confirmed a triple dissociation in the timing, source, and spectral features of typical alpha modulations at the parcel level. Ipsilateral alpha-increases occurred early, over occipital regions, at a high alpha-frequency (10-14Hz), specific to spatial attention. Contralateral alpha-decreases occurred later, over parietal areas, at a lower alpha-frequency (7-10Hz), associated with attention deployment in general. These dissociations were also linked with eye movements and were missed when using the alpha-lateralization index, obscuring specific anatomical contributions to the well-known alpha asymmetry in attention. Large-scale network synchronization analyses are underway to assess the functional significance of high-alpha and low-alpha phase synchronization in coordinating neuronal communication during visuospatial attention. Conclusions: Our findings suggest that perceptually relevant alpha-increases may indicate a reflexive mechanism filtering out irrelevant information, while alpha decreases reflect endogenously controlled mechanisms for processing relevant information. We are currently exploring the role of large-scale network synchronization driving these proposed mechanisms.

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Perceived Stereo Depth reflects Retinal Disparities, not 3D Geometry

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We present a new illusion that challenges our traditional understanding of stereo vision. Traditional 'Triangulation' accounts of stereo vision back-project from points on the retina to points in the world. This requires that stereo vision incorporates how binocular disparities fall off with the viewing distance squared. By contrast, Linton proposes a 'Minimal Model' of stereo vision where perceived stereo depth is simply a function (most likely a linear function) of the amount of disparity on the retina. We present a new illusion (the 'Linton Stereo Illusion') to adjudicate between these two approaches. The illusion consists of a smaller circle (at 40cm) in front of a larger circle (at 50cm), with constant angular sizes throughout. We move the larger circle forward by 10cm (to 40cm) and then back again (to 50cm). The question is, what distance should we move the smaller circle forward and back to maintain a constant perceived separation between the circles? Constant physical distance (10cm) ('Triangulation') or constant disparity (6.7cm) ('Minimal Model')? Observers choose constant disparity. This leads us to four conclusions: First, perceived stereo depth appears to be best captured by the 'Minimal Model'. Second, doubling disparity appears to double perceived depth, suggesting that perceived stereo depth is proportional to disparity. Third, changes in vergence appear to have no effect on perceived depth. Fourth, stereo 'depth constancy' appears to be a cognitive (not perceptual) phenomenon, reflecting our experience of a world distorted in perceived stereo depth.
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Visual Measures as Language-agnostic Early Predictors of Reading Ability

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Reading is a complex skill influenced by a child's underlying neuro-biology as well as the environmental and instructional context. Disentangling the influence of biological traits from environmental factors could support early identification and intervention for children who are at risk of dyslexia and other struggles with reading. Our findings show that visual-processing measures may provide a window into biological contributors of reading skills that are agnostic to language and socioeconomics. We tested the multi-element processing (MEP -with letters (L) and pseudo-letters (P) - agnostic to script-type) and motion sensitivity (Motion, a non-script based) tasks that have been shown to have the strongest evidence for identifying a subgroup of struggling readers not identified by conventional, language-based measures. In a series of studies we leveraged item response theory (IRT) to design and optimize gamified, online versions of these tasks to be quick, valid and reliable (MEP: 0.86, MP: 0.84), and easy for children in a school setting. We then administered these measures to a large, diverse and representative sample of kindergarteners and first graders in California public schools (N = 1401). Our results showed that task performance was equivalent in children who spoke English versus Spanish as a primary language as did children that qualified for free and reduced price lunch versus those who did not, across all visual measures in kindergarten. We next examined each visual measure as a predictor of reading development and found that (1) the MEP tasks account for 15.3% and (2) the Motion task accounts for 4.6% of variance in end-of-year reading measures in kindergarten. Most screening measures are biased by environmental factors leading to inequitable screening performance in a diverse-school setting. Our findings show that visual-processing measures predict reading skills and are not affected by language proficiencies or socioeconomic status as early as kindergarten.
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Individual differences in 12-month-olds' pupillary responses to size and luminance of stimuli

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Measurement of pupil dilation is increasingly applied to investigate cognitive processes in infants. However, in addition to psychologically induced changes in pupil diameter, parameters such as differences in the stimulus' luminance or participants' gaze direction can affect pupil measures. Infants are likely to move their eyes freely across a visual scene. Even if experimental conditions are generally controlled for luminance, unpredictable fixation locations on stimuli that vary in luminance will lead to confounds or noise in pupil measurement. In the adult literature, local pupil contrast was successfully measured with a 10° circular mask around fixations and used to adjust pupil data. However, same-aged infants can vary considerably in their visual development. To our knowledge, it is not yet known whether similar interindividual differences exist in infants' pupillary responses to luminance contrasts. Here, we investigate the possibility of predicting pupil light reflexes in infants. Twelve-month-olds (N = 93) saw disks of different sizes (9.5°, 13°) and in two luminance levels (light and dark grey) at several locations on a medium grey background, matching areas of interest (AOIs) in a larger pupillometry study. Additionally, light and dark grey backgrounds were alternating without disks. Animated attention grabbers with the same luminance levels were placed centrally on the AOIs. Data analysis is ongoing. Because a radius that most closely approximates pupil contrast in infants is not yet known, we will compute mean pixel intensity around each fixation in different radius sizes. With this, we plan to find out how pupil size varies with the size of an area of different contrast. We will also determine interindividual variability in the onset and duration of infants' pupil adaptation to the changing luminance levels.

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Scanning and crossing virtual streets with hemianopia; A step to successful crossings

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Individuals with hemianopia may benefit from adopting adequate scanning to successfully cross streets. However, identifying what constitutes adequate scanning remains challenging, since it is near impossible to ensure standardised and sufficiently challenging, yet safe real-world situations. While acknowledging its various limitations, virtual reality may offer a potential solution. Therefore, we used a virtual environment to compare scanning and crossing behaviour between individuals with hemianopia and those with unimpaired vision and between high- and low-performing people with hemianopia. Individuals with homonymous hemianopia (N=18) and unimpaired vision (N=18) crossed a virtual street displayed in a head-mounted display. Virtual cars approached from both directions, travelling at a speed of either 30 or 50 km/h. Participants' crossing and scanning behaviour was recorded and analysed in terms of the selected crossing gap duration, the time-to-contact after crossing and the gaze direction towards the blind hemifield. High- and low-performance was defined as showing relatively long or short time-to-contact, respectively. On average, individuals with hemianopia showed similar crossing and scanning behaviour to those with unimpaired vision. All participants chose a shorter gap duration and exhibited a shorter time- to-contact at a higher car speed. High-performing individuals with hemianopia showed a slight increase in gaze direction (approx 2.5°) towards their blind hemifield in the final four seconds before crossing when cars travelled at 30 km/h, but not at 50 km/h. Within our simulated environment, hemianopia did not influence scanning and crossing behaviour. Individuals with hemianopia may, however, benefit from making larger gaze scans towards the blind hemifield just before crossing. Inaccurate car speed perception likely influenced behaviour, potentially masking the role of adequate scanning at higher car speeds. To translate virtual outcomes to real-world applications, it is imperative to improve participants' car speed perception in virtual reality displays, possibly through increasing display resolution or augmenting visual cues.
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A TMS test of hemispheric dominance for visual shape processing

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A previously published case study presented a patient, SM, with a right lateralised lesion resulting in object agnosia (Konen et al., 2011). This could suggest a right hemispheric (RH) dominance for object processing. We aimed to test this idea, hypothesising that transcranial magnetic stimulation (TMS) of shape-responsive visual cortex in the RH would cause a greater reduction in shape discrimination performance than TMS to the homologous left hemisphere (LH) region or control sites. Ten neurologically typical participants completed psychophysical testing to determine baseline individual shape discrimination thresholds. TMS targets in each hemisphere were localised through functional MRI (fMRI) with experimental target sites occupying a commensurate region to SM's lesion in the RH and a homologous region in the LH. Control sites (V5/MT+) in each hemisphere were defined using a probabilistic atlas. Participants then completed four counter-balanced repetitive TMS sessions (LH/RH, target/control), whilst completing a same-different shape discrimination task. Comparing experimental vs. control conditions in the RH vs. LH, or averaged across hemispheres, revealed no significant differences in sensitivity or reaction time measures. This result likely reflects the impact of additive noise in the statistical comparisons. When directly comparing experimental sites between hemispheres, significant decrements in shape discrimination sensitivity were associated with RH disruption. Further, an exploratory mixed effects analysis using trial-level data revealed significantly increased reaction times following disruption of the RH experimental target region. These results provide two complementary lines of evidence suggesting that disruption of a RH shape-responsive region commensurate with SM's lesion location causes greater decrements in shape discrimination performance compared to LH stimulation. This pattern of results requires confirmatory follow-up with a larger sample, but could be indicative of a right hemispheric dominance for visual shape processing.

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Better to measure colour constancy with coloured rather than grey surfaces

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Colour constancy is often measured with grey settings: participants adjust the colour of a surface in the scene to appear grey. For perfect constancy, the settings should correspond to the colour of the illuminant, thought to be discounted from all surfaces in the scene to stabilize colour appearance. However, the visual system does not access full spectral information, and perfect colour constancy can be achieved by discounting the illuminant only for neutral surfaces and can only be approximated for coloured surfaces. In fact, the colour changes due to an illumination change in a 3D colour space vary depending on the spectral reflectance of each surface. In this work, we evaluated how much illumination estimates can predict colour constancy for surfaces of different colours. We rendered photorealistic computer graphics scenes under 4 different illuminants. A sphere was placed in the centre of each scene, and its reflectance was set to 8 different colours, spanning the hue circle in CIE Lab colour space. We used an asymmetric colour matching task to measure colour constancy for the different surface colours, as well as grey settings, to obtain an estimate of the four illuminants (N=6). Then, we applied a Von Kries transform to predict colour constancy for the 8 coloured surfaces based on the illumination estimates obtained with the grey settings. Colour constancy showed significant variations across different surface colours and illuminations (Q1=10%, Q3=86%, Median=44%). The pattern of variation was correlated across observers, as indicated by the average correlation coefficient across all pairs of participants (r=0.22). However, the predicted colour constancy based on the Von Kries transform correlated much less with the measured one (r=0.04; t(5)= 4.363, p=0.007).Our results suggest that grey settings do not accurately measure colour constancy for coloured surfaces, or that the Von Kries transform may not provide accurate predictions.
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What do similarity tasks actually measure? A systematic comparison of eight tasks.

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Perceived similarity judgments play a critical role in the measurement of mental representations, offering a pathway to understanding how we represent what we see. Numerous similarity tasks are used routinely in research on object perception that estimate perceived similarity with a broad range of behavioral techniques. Despite decades of their use, the degree to which these tasks are measuring the same construct and their relative reliability and external validity are largely unknown. To address this issue, here we systematically compare different similarity measures using eight common tasks: 1) pairwise ratings, 2) single arrangement and 3) multiple arrangement, 4) triplet odd-one-out judgments, 5) pile sorting, 6) a speeded visual search, 7) speeded same-different judgments, and 8) sequential forced choice similarity judgments (SFCS). The latter is a novel and, potentially, more time-efficient alternative to the traditional odd-one-out task. We will compare these tasks using their within-observer and between-observer reliability, efficiency (data acquisition speed), degree of covariation, and agreement with behavioral categorization and neuroimaging data (fMRI and EEG). Preliminary results indicate striking similarities between many tasks with more fine-grained differences, while also showing stronger differences between other measures, such as speeded tasks vs. non-speeded tasks. In addition, tasks varied in the degree to which they cover more visual or more semantic information. Together, this research promises to allow us 1) to determine the role of the task on mental representations of visually perceived objects, 2) to understand similarities and differences between tasks, and 3) to identify which tasks are best suited for different types of experiments and research questions.

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Eyeing motion: Effects of moving stimuli on attention of spider-fearful participants in a free-viewing paradigm

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Studies with various paradigms (e.g. dot probe, visual search) have shown that the attentional pattern of anxious individuals is characterized by the hypervigilance-avoidance effect, marked by an early attentional focus and subsequent turning away from threatening stimuli. Strikingly, previous studies have predominantly relied on static stimuli, neglecting the fear-inducing effects of the factor motion. This study aims to address this gap by examining the occurrence of the hypervigilance-avoidance effect when adding motion as a variable. We hypothesized that indices of early attentional processes will confirm findings of an automatic and rapid orientation towards threatening stimuli. Further it is assumed that the high salience of motion will inhibit the subsequent attentional disengagement from threatening stimuli. To test these hypotheses, eye movements of individuals with and without spider fear were compared in a free-viewing paradigm to record sheer attentional avoidance rather than active behavioral avoidance. Fear of spiders was used due to its high prevalence in the population, with a control group included to specifically assess the role of motion. Each trial, an image or a video of a spider or beetle (control stimulus) from a set of 60 stimuli was presented for five seconds. The comparison included first fixations, dwell time, saccadic latency, speed and acceleration of the first saccade which were chosen based on previous studies to explore specific influences of motion (e.g. first fixations were assumed not to be suitable to differentiate between groups when presented with moving stimuli). Final data are currently being collected. If attentional patterns between moving and static stimuli differ – for example indicated by a longer dwell time of spider-fearfuls on spider stimuli compared to a more exploratory behavior of the control group – it suggests the need to examine the influence of naturalistic features, such as motion, in the investigation of well-known phenomena.

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The role of stimulus-response mapping in serial dependence

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Human perceptual decisions are serially dependent and biased towards previous trials. The factors contributing to serial dependence, and particularly the role of prior stimuli or responses are still debated. In this study, we investigated the role of the type of response and stimulus-response mapping. In four experiments, participants performed an orientation judgment task with several types of responses, each requiring the mapping of circular features (orientation) onto different formats, including circular, linear, and binary. We measured serial dependence in blocks involving the same type of response and blocks where different types of response alternated. Overall, we found attractive serial dependence —i.e., a bias towards prior stimulus orientations— in all cases except after trials in which binary choice responses were delivered immediately after the stimulus. Surprisingly, however, we found no correlation between the strength of serial dependence measured with different types of continuous responses, namely linear and circular, suggesting that the response tool and stimulus-response mapping space does indeed play a role.
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More Than Meets the Eye - Conceptual Beliefs Predict Naturalistic Face Impressions Across Cultures

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Face impression research has heavily focused on linking visual facial cues with specific trait impressions – for example, smiling faces are perceived as trustworthy, mature masculine faces as dominant. However, recent accounts suggest that observers' individual differences contribute to face impressions equally to visual cues. The Dynamic Interactive framework suggests that person or culture-specific social conceptual knowledge, such as preconceived beliefs about what others are like (conceptual beliefs), shapes people's impressions of faces. However, the relationship between conceptual beliefs and face impressions has only been tested on standardised young White male faces and Western (US) perceivers, which might not represent how people form impressions of highly variable face images and/or across cultures. Thus, here in three studies we investigated the relationship between conceptual beliefs and own and other-culture naturalistic face impressions in British and Chinese participants using representational similarity analysis. In Study 1 we demonstrated that British conceptual beliefs positively predict White naturalistic face impressions even when faces provide rich information. In Study 2, we found that individuals' conceptual beliefs reflect individual variability in naturalistic face impressions and that both conceptual beliefs and face impressions are socially shared across distinct participant groups within the British culture. In Study 3 we found that Chinese participants' conceptual beliefs predict Asian naturalistic face impressions. Furthermore, conceptual beliefs reflected naturalistic face impressions similarly across British and Chinese cultures and own and other-culture faces. Together, these studies are the first to demonstrate that conceptual beliefs reflect face impressions even when face stimuli provide rich visual information, and that the extent of this relationship is comparable within British culture and across British and Chinese cultures. Our findings extend the Dynamic Interactive framework to highly variable faces and culturally diverse participants, suggesting that conceptual beliefs might be a mechanism of face impressions which is shared across cultures.
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The Development of Mooney face Perception in 6-11-month-old infants

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The Mooney faces are two-tone face images that have degraded individual features (e.g., eyes and mouth) and retain shadows and highlights (Mooney, 1957). Previous research reported that even young infants can detect faces from Mooney face images, despite degraded features of the images. For instance, 3-4-month-old infants preferred upright over inverted Mooney faces with isolated (relatively low-degraded) features (Otsuka et al., 2012), and 18-month-old infants showed an upright preference even for Mooney faces without isolated (relatively high-degraded) features (Doi et al., 2009). However, the developmental process of face detection from Mooney faces between the two ages (3-4 months and 18 months) remains unclear. Thus, we examined whether infants aged 6-11 months detect faces from Mooney faces with and without isolated features. In Experiment 1, we tested the upright preference for Mooney face images under four conditions regarding the degradedness of individual features in the images: slightly-degraded-features, moderately-degraded-features, highly-degraded-features, and extremely-degraded-features. In each trial, upright and inverted Mooney face images were displayed side by side for 10 sec. Because two trials were conducted for each of the four image conditions, each infant participated in a total of 8 trials. Forty-five 6-11-month-old infants participated in Experiment 1. The results indicated that the infants showed significant visual preferences for the upright over inverted images under the slightly- and moderately-degraded-features conditions. Additionally, in Experiment 2, we also tested the infants' upright face preference for the original non-degraded face images and confirmed that they showed a significant upright face preference for the original face images. The results of two experiments suggest that although the infants aged 6-11 months consistently showed the upright face preference even for Mooney face images with relatively modest degradedness, their ability to detect face figures from Mooney face figures was still immature.

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Influence of gaze cueing and semantic violations on visual memory and metamemory for real-world scenes

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Viewers follow others' gaze and use semantic expectations about what objects a real-world scene likely contains in order to guide attention. We tested how this influences long-term memory in young (18-40 years) and older (64-87 years) adults. In an online study (Exp.1), we used images of everyday environments containing multiple objects and a young or older person looking at or away from an object (tested) that was either semantically consistent (expected) or inconsistent (unexpected). Participants first memorised all the scenes for 10s each. At test, they indicated the identity of the tested object by choosing one of four names, and then, as an index of metamemory, rated confidence in their response. The same scenes, but including only a young person, and the same procedure were used in an eye-tracking, lab study (Exp.2) with only young participants, in which we also collected remember/know responses as another index of metamemory. We found that cueing the object with gaze improved accuracy in Exp.2, and increased metamemory in both experiments, similarly for correct and incorrect responses. Inconsistency increased metamemory but only for correct responses (Exp.1-2), and this could not be explained by a longer fixation time on inconsistent objects during encoding (Exp.2). These gaze cueing and consistency effects were independent of both the participant's age and the person's age in the scene. They show that potential social relevance signalled by others' gaze may enhance recognition memory, but its impact on metamemory might not be a reliable indicator of veridical representations. Semantic inconsistency may act primarily by enhancing the specificity of the memory trace and the viewer's knowledge of their own memory.

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Sense of embodiment and motor performance of the co-embodiment hands in a virtual environment

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Humans can embody a virtual avatar through visual-motor synchrony. Two individuals can embody an avatar by averaging their movements or by dividing/sharing avatar's body parts (virtual co-embodiment). The sense of embodiment and the motor behavior have been investigated using whole-body avatars. However, it has not been well investigated whether we can co-embody a hand and fingers by two individuals, and how this affects the sense of embodiment, performance, and motor behavior. In the experiment, 15 dyads (N=30) performed the finger reaching task with Solo-Hand (all fingers were synchronized with the movement of one participant), Averaged-Hand (all fingers were synchronized with the averaged movements of the dyad), and Divided-Hand conditions (the thumb, index, and middle fingers were synchronized with the movement of one participant, while the other fingers were synchronized with another). Participants wore a head-mounted display and observed a robotic hand at the location of the real hand. They were asked to touch a red ball with one finger as quickly as possible. The balls appeared randomly at 4 cm from either the index, middle, ring, or little finger with 700, 850, or 1000ms SOA. Participants were blind to the hand conditions during the experiment. We found that the sense of body ownership and agency were similar for Solo-Hand and Averaged-Hand conditions, and significantly decreased for the Divided-Hand condition. Averaged-Hand showed the significantly highest reaching performance when the task difficulty was intermediate (850ms SOA), while Divided-hand showed the worst performance. The finger movements of Averaged-Hand were the smoothest (least jerky). These results suggest that the co-embodiment hand by averaging two individuals' movements could have general advantages over the divided-finger co-embodiment for the sense of embodiment, and might be even better than the normal, single-controlled hand for the motor performance in reaching and smoothness.
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The effect of face and language familiarity in the perception of audiovisual speech synchrony

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The temporal integration of audiovisual speech does not require precise temporal synchronization of sound and video but permits a certain degree of temporal asynchrony. While several studies have indicated that familiarity with the speaker influences the temporal processing of audiovisual speech, it remains unclear whether this is due to the familiarity with a speaker's face or with a spoken language. In this study, we investigated how familiarity with the speaker's face and spoken language modulates audiovisual temporal processing. We adopted 2 by 2 within-participant design in a combination of speakers' faces (familiar and unfamiliar) and spoken languages (native and non-native). Auditory stimuli (i.e., voice) and visual stimuli (i.e., lip movements) were presented with a small temporal gap within ± 300 ms. p, which was followed by the participants' judgment of the synchrony of audiovisual stimuli. Then we calculated the temporal binding window (TBW) and point of subjective simultaneity (PSS). These procedures were pre-registered in OSF (https://osf.io/bvrxa). Our findings revealed that the width of TBW for audiovisual speech was broader with the familiar faces rather than with the unfamiliar faces, regardless of the spoken language. Additionally, the familiarity with the speaker's face influenced the PSS, wherein the auditory and visual stimuli were subjectively perceived as simultaneous when visual stimuli were presented before auditory stimuli. This tendency increases with audiovisual speech with familiar faces, regardless of spoken language. These results suggested that familiarity in the visual domain, rather than the auditory domain, impacts the temporal processing of audiovisual speech.

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Facial Identification in Peripheral Vision and Flashed Face Distortion Effect

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Flashed face distortion effect (FFDE), where normal faces are perceived as distorted and uncanny, occurs when we see faces that rapidly switch in the peripheral vision. This effect may be due to the difficulty in identifying faces in the peripheral vision. Studies suggest that FFDE is weakened when stimuli are presented in the central vision, where facial identification is easier. This study aims to investigate the relationship between facial identification performance and FFDE strength. In the FFDE task, participants observed faces presented in their peripheral vision for 10 s (250 ms per face stimulus) and rated the intensity of the distortion and uncanniness of the stimuli on a 7-point scale. In the facial identification task, two face test stimuli were presented on the left and right sides of a screen for 250 ms. Subsequently, the target face, which was or was not presented as one of the test stimuli, was presented at the center of the screen. The participants answered whether the identity of the target face matched that of either of the two face test stimuli. This study manipulated the eccentricity (2°, 4°, and 6°) and stimulus size (1° and 4°) of the face stimuli in the FFDE task and test stimuli in the identification task. Results showed that eccentricity had less effect on the FFDE when the stimulus size was small. Conversely, the distortion was stronger with larger eccentricity when the stimulus size was larger. In the identification task, the correct response rate decreased with increasing eccentricity. Furthermore, the facial identification performance and FFDE intensity correlated negatively when the stimulus size was large. These results suggested that the difficulty of face identification might be a partial cause of the weak FFDE in the peripheral vision.
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An Exploratory Factor Analysis of Visuoperceptual Reading Symptoms in Adults with Visual Stress

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BACKGROUND: Visual Stress is a condition characterised by visuoperceptual distortion symptoms, such as words 'moving/merging' and patterns/colours seen within text when reading. Coloured filters (tinted spectacle lenses and acetate sheets/overlays) have been proposed to ameliorate visual stress symptoms. However, visual stress diagnosis is on an ad-hoc basis, with symptomology and diagnostic criteria poorly understood. This study comprehensively investigated visuoperceptual reading symptoms in adults with/without visual stress to develop a clinically useful questionnaire for visual stress diagnosis. METHODS: After scrutiny of research literature/clinical reports, a 17-item Likert-scale questionnaire was developed probing reading comfort and symptoms. 1,248-adult undergraduate students (aged 18-36-years,) completed the questionnaire and a Pattern Glare test (black and white gratings at 3 cycles per degree), which was used to determine presence of visual stress. Demographic information and brief ocular/medical history were also probed. 294-participants (23.6%) exhibited pattern glare (presence of >3 pattern glare symptoms). After exclusion of diagnosed migraineurs (n=47), questionnaire data from 247-participants (193F:49M:5N) were analysed. Parallel analysis proposed 5-factors exist within the construct. Principal axis factor analysis with promax rotation (k=4) was conducted. Items with >5% missing data were deleted. Items with >80% of responses satisfying one category were deleted to avoid floor/ceiling effects. Items which strongly cross-loaded (>0.3) onto more than one factor were excluded. RESULTS: Five factors identified by exploratory factor analysis mapped well to aetiological theories proposed to explain visual stress: 1) Magnocellular Pathway Deficits 2) Cortical Hyperexcitability 3) Eye Movement & Tracking Issues 4) Aversion to High Temporal Frequency 'Flicker' and 5) Concurrent Pathologies associated with Visual Stress. Post-hoc item analysis reduced questionnaire content to 10-items. CONCLUSION: Exploratory factor analysis enabled systematic creation of the first robust 10-item questionnaire to aid visual stress diagnosis. Further work is needed to apply in a clinical context and among different age ranges for validation purposes.
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Action learning with unconscious stimuli: transfer across retinal location and orientation

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The specificity and generalization of perceptual learning and the circumstances under which perceptual learning can transfer to untrained retinal location and orientation have been investigated for decades. Our previous study found that action learning was more effective than perceptual learning when the stimulus was invisible by continuous flash suppression (i.e., without conscious awareness of the stimulus). However, it is unclear whether action learning was advantageous over perceptual learning for the generalization across retinal location and orientation. To test whether there are advantages, participants were randomly separated into two groups. One group of participants was trained to insert a card into an invisible open rectangle ("action training group") that was either vertically or horizontally oriented (randomly selected for each trial) and was presented on either the left or the right visual field (counterbalanced across participants). The other group of participants followed the identical experimental protocol but were trained to orally report the orientation of the open rectangle ("perception training group"). We found that after seven days of action training, the contrast sensitivity and action performance increased at the trained location, and the learning effects transferred to the untrained location. In contrast, perception training did not yield significant changes in contrast sensitivity or perception performance at the trained or untrained locations. To investigate generalization across orientations, participants underwent a similar experimental procedure as the action training group, with the training orientations of stimuli being clockwise and counterclockwise rotated by 15° from the horizontal orientation (0°). The tests after training centered at the trained orientation (i.e., 0°) and three untrained orientations (45°, 90°, and 135°). The results showed significant contrast sensitivity and action performance increased for all the trained and untrained orientations. Our

study suggests that unconscious action learning was advantageous over perceptual learning in generalization across retinal location and orientation.

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Foraging for famous faces: Exploring the interaction between facial expression and facial identity processing

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Understanding the intersection between facial expression and facial identity processing has long been a focus of face perception research. Here, we adopted a foraging paradigm to explore whether categorising an emotional expression is independent of facial identity in the context of multiple-target search. Stimuli consisted of AI generated images of male celebrities, each providing 4 exemplars to fill a 2 (valance) x 2 (arousal) expression space. Specific expressions were characterised as: a slight smile, full laughter, a slight frown, or extreme anger. In separate trials, participants (N=12) searched on an iPad for positive amongst negative facial expressions (or vice versa) irrespective of the level of arousal (high or low) depicted in the images. Each display contained an array of 40 faces: 20 target expressions, 20 distractor expressions. The position of each facial image was dynamically updated to reduce spatial search strategies and to make the task more demanding and engaging. The crucial manipulation was whether all faces within a trial shared the same identity or whether identity varied, with images being sampled from the full set of celebrities. Data were analysed using a 2 (Identity: Same/Different) x 2 (Expression: Positive/Negative) factorial design. Results were clear. Participants were able to select successive targets at a rate of approximately 950 ms/target during same identity trials, but were slowed to a rate of 1294 ms/target for different identity trials. There was also an effect of expression type, with the search rate for positive expressions (1042 ms/target) being faster than for negative expressions (1206 ms/item). There was no interaction. Overall, these findings provide further evidence that the processing of identity and expression is unlikely to occur independently, and also demonstrates the way in which foraging tasks can be used with complex stimuli, such as faces.

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Does Perceptual Salience Explain Altered Social Categorisation in Children with Autism Spectrum Disorder?

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A social categorization paradigm, based on permanent versus transient visual traits has been introduced to study the differences in social categorization between children with autism spectrum disorder (ASD) and their neurotypical controls (Kiss et al., 2021). When given a choice between permanent features such as hair colour or skin tone as opposed to a transient feature (clothing colour) neurotypical children rely on both permanent features with equal probabilities, while ASD children seem to prefer hair colour and disregard skin colour. However, due to the unbalanced nature of the applied stimuli in terms of primary perceptual features (e.g., luminance contrast, hue saturation, stimulus area), it is not clear whether these results are related to different social categorization strategies or driven by lower-level perceptual salience affecting the decisions of ASD participants more strongly. In this study, first we substantially modified the visual characteristics of the original stimuli in order to balance perceptual salience between the potential permanent versus transient choices, however, stimuli were still presented on printed cards. The original tendency for ASD children not relying on skin tone remained, although still with an uncertainty about the interpretation as a strong bias towards transient feature-based choices occurred in all participants. In order to clarify the picture, we then adopted computer generated stimuli to avoid saliency issues arising from printing. Since this introduces a communication difficulty with ASD participants with respect to the response (they cannot simply place the cards in different packs in the computerised version), we introduced eye-tracking to register implicit responses and the pattern of gaze. The results will inform the field about the background of altered social behaviour in ASD and will clarify whether it may be due to an innate difference in social categorization itself or based on differences in low level perceptual processing.

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The association between sensory sensitivity, mental imagery abilities, and divergent perception

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Perception is shaped by both bottom-up input from the senses and by prior information that exerts a top-down influence. A disrupted balance between top-down drive and bottom-up input is hypothesised to underlie divergent perception, e.g., hallucinations, or synaesthesia. Here, we use survey data (N=120) to test whether in individuals with perceptual extremes, e.g., with very strong/weak mental imagery (a top-down process) or high/low sensory sensitivity (bottom-up input), divergent perception is therefore more prevalent. We assess divergent perception with the Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE). Divergent perception may furthermore link to stronger (subclinical) psychiatric traits. Results for sensory sensitivity show that the hypersensitivity subscale of the Glasgow Sensory Questionnaire (GSQ) and the Sensory Processing Sensitivity Questionnaire (SPSQ) score positively predicted the score on the O-LIFE unusual experiences subscale (i.e., positive schizotypy). For mental imagery, however, the Vividness of Visual Imagery Questionnaire (VVIQ) score did not predict O-LIFE outcomes. Low scores on the VVIQ did correlate negatively with the Autism Quotient (AQ) Imagination subscale. A Principal Component Analysis revealed three principal components in the data, each centring around a different aspect of sensory sensitivity. The GSQ hypersensitivity subscale formed a principal component together with ADHD, depression, anxiety, and the O-LIFE unusual experiences and impulsive nonconformity subscales. The positive dimension of the

SPSQ formed a principal component with AQ-Attention to detail and (negatively) with AQ-Imagination. The negative dimension of the SPSQ formed a principal component with AQ-Social skills, AQ-Communication, AQ-Attention switching, and the O-LIFE cognitive disorganization subscale. The data suggest that stronger sensory sensitivity is related to a stronger tendency to experience divergent perception, and is linked to subclinical psychiatric traits. Imagery vividness appears to play a smaller role. Next, we seek to link our findings to self-reported experiences of synaesthesia, and to replicate the results using Dutch questionnaire translations.
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Detecting motor perturbations across modalities and tasks

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Recently, interest has increased in the cognitive side of sensorimotor adaptation: For example, how knowing when and how to correct your actions to suit the task at hand affects sensorimotor adjustments. Comparatively less is known about when humans notice motor errors, leading them to employ such cognitively controlled corrections. Here, we investigated how well and through which cues participants can detect motor perturbations, and compared this across different types of motor actions, perturbation types, and tasks. We conducted three experiments (N=48 each) using (a) visuo-haptic size mismatches in grasping with a relative-size-judgement task that was either 2AFC (experiment 1) or 4AFC (experiment 2), as well as (b) split-belt speed perturbations in walking with a 2AFC task (experiment 3). Different perturbation schedules were used to induce different degrees of sensorimotor adaptation in the grasping tasks, allowing us to dissociate perturbation magnitude and the motor error, both of which have been hypothesised to help participants notice motor perturbations. We found that detection performance in grasping depended both on the magnitude of the perturbation and degree of adaptation, as participants showed decreasing performance over time when exposed to constant perturbations, but not with regularly changing perturbations, and overall smaller JNDs in the latter. Patterns were virtually identical in 2AFC and 4AFC tasks. In walking, our primary comparison was between different types of perturbation (split-belt acceleration vs. deceleration, i.e., slip vs. stumble). We saw that detection performance of these two types was highly correlated between participants, despite overall much larger inter-individual differences compared to grasping. Overall, this shows that participants do indeed use different types of cues to detect motor perturbations (perturbation magnitude as well as trial-wise error), and that there are pronounced differences between different motor actions and perturbation types that are consistent across tasks.
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Larger bias in microsaccades during shifting than during sustaining covert visual-spatial attention

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Small fixational eye-movements known as microsaccades have often been reported to track the focus of covert selective attention, but the reliability of using microsaccades as an indicator of covert attention has also been brought into question. Because attention comprises different processes and stages, it is conceivable that microsaccades may be particularly correlated with some stages and less so with other stages. For example, a recent study found no directional bias of microsaccades towards a visual target in a sustained visuospatial attention task. In contrast, we and others have systematically found robust microsaccade biases in tasks requiring shifting (rather than sustaining) covert selective attention. In order to study whether microsaccades correlate predominantly with shifting covert attention, sustaining covert attention, or both, we developed an orientation-change detection task. The task involved shifting covert visual-spatial attention to a target and sustaining it until an orientation change was detected. This change would occur after a delay that varied unpredictably between 500 and 3200 ms after the attentional cue. This enabled us to investigate whether and how microsaccades track these respective attentional stages. The results show that (1) the direction of microsaccades are significantly biased towards the covertly attended visual object during both shifting and sustaining attention, but that (2) this bias is significantly more pronounced during attentional shifting. These findings may help explain why the correlation between microsaccades and covert selective attention is more robust in certain attention tasks than in others.
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The Role of Cognitive Control in Discrete Perception as Evidenced by Postdictive Illusions

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Postdictive effects are pivotal evidence supporting discrete perception, a concept recently once again gaining attention in cognitive psychology. We propose that elucidating the organization principles of discrete perception can enhance our understanding of cognitive information processing and clarify consciousness' role in that process. Our study investigates how the perceptual window's duration alters under varying conditions and the potential processes within and between such windows. We speculate that information complexity, spatiotemporal proximity, and task demands, as mediated by cognitive control and categorization processes, affect this duration. Our experiments utilized audiovisual illusions with postdictive effects, where the simultaneous presentation of sound and flash in two stimuli generates an illusory flash when only the sound is present between them. In our first experiment, we varied interstimulus intervals (50 ms to 800 ms) and time proximity towards one of the other stimuli. Our second experiment introduced varying flash colors, switching from the traditional gray to red and green in different presentation configuration. Results demonstrate a consistent illusion across intervals, with more robust illusions at shorter intervals ($F(1,46) = 151.99$, $p < .001$). Interestingly, color changes led to participants

missing an actual middle flash when presented, especially when its color matched the final stimulus, while matching the initiating flash's color reduced the effect ($F(3.3, 178.33) = 8.102$, $p < .001$). We propose that this occurs due to the categorization of information within each perceptual window. It seems like information is coded during perception in terms of objects and different categorizations and then gets deciphered by consciousness mechanisms. Illusions are created in a way that messes with a coding system. Understanding postdictive illusions from this angle may offer valuable insights into the processing of visual illusions and advance the study of discrete perception.

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Comparing Social Gaze between Communication Media

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Video-mediated communication (e.g., Zoom) has become prevalent for remote communication, but often falls short of the communicative efficiency of face-to-face interactions. This is primarily due to the disruption of non-verbal cues. Specifically, genuine eye-contact cannot be achieved. Much research exists comparing the efficiency of videoconferencing to face-to-face communication, yet few studies directly examine how social gaze is affected by these media. Here, we investigated differences in gaze behaviour between dyads communicating face-to-face versus over Zoom. Simultaneous direct gaze occurs when both participants look directly at each other's eyes at the same time. In face-to-face communication simultaneous direct gaze results in an eye contact event. In Zoom settings, however, this is not the case. We recorded eye gaze and head orientation from both participants while playing the Heads-Up game in three communication conditions: (1) regular face-to-face, (2) face-to-face through a screen-sized window cut into a barrier (to address any artifacts introduced when transitioning to a smaller subtension), and (3) over Zoom using two iPads in the same barrier. While playing, the role assigned to participants was varied, so that each participant spent half of the game as the “questioner” and half of the game as the “responder”. Simultaneous direct gaze events were significantly more frequent and of longer duration on average in the face-to-face conditions compared to over Zoom. These patterns were consistent when examining direct gaze behaviour. When analyzing the effect of role, the data indicated that there were more direct gaze events when participants were responders than when they were questioners. Altogether, these findings highlight the impact videoconferencing has on gaze and provides evidence for the idea that this disruption may be driving many of the negative impacts sensed when communicating over Zoom.

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Psychophysics Reveals a Failure of Grouping in Current Deep Neural Networks

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Particular deep neural networks (DNNs) are considered good models of the ventral visual stream, as assessed by neural alignment with primate neural and behavioral data. However, they have not thoroughly been evaluated on psychophysical tasks, and the extent to which DNN models do or do not align to human behavior in the edge cases of vision thus remains unclear. Here, we compared DNN and human performance in recognizing fragmented images, a standard task in psychophysics. Specifically, we presented sparse fragmented objects from 12 categories to 50 human participants and 14 pre-trained models. We gradually increased the number of fragments of each object and evaluated the performance of human observers and models at these different fragment densities. In line with classical psychophysical studies, human performance scaled logarithmically with the number of fragments. While models showed high accuracy with fully colored images, their performance declined (51% correct on average) with images showing full contours of objects, contrary to humans who excelled in this condition (98% correct on average). Similarly, humans reached high performance at the highest fragments density presented (83% correct on average), but models were close to chance levels (11% correct on average). Not a single model was able to solve this task, including models trained specifically on shape recognition. Adapting models to fragmented object images via a decoder trained on training images of the same distribution resulted in better-than-chance performance but still left a large gap to human data (contours: 67% correct; max fragments density: 42% correct). Taken together, these findings indicate a substantial failure case in the ability of current DNNs to fully model human visual processing.
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Representation of Sex from the Face and Body: Evidence from a Visual Adaptation Task

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Observers readily make judgments of sex from the appearance of others' faces and bodies. Researchers have used visual adaptation techniques with such social stimuli to demonstrate high level after-effects such that ambiguous bodies or faces appear more male or female following adaptation to a female or male adaptor. Such findings have typically been interpreted in terms of a symmetrical mental 'space'. However, previous evidence from visual search tasks suggests that ‘female’, in both body shape and in face appearance, is coded as an extension of a ‘male’ default. That is, there is an asymmetry in the representation of ‘male’ and ‘female’ in the perceptual system. This hypothetical polarised representation of sex predicts asymmetric effects of adaptation in adaptation paradigms. However, to our knowledge, there are no attempts in the literature to directly compare the strength of the perceptual aftereffect of adaptation for ‘male’ versus ‘female’ faces and bodies. To this end, we utilised a visual adaptation paradigm, where participants were exposed to computer-generated strongly female, strongly male, or perceptually ambiguous faces and body silhouettes (adaptors) and were then asked to categorise subsequent slightly male, slightly female, or perceptually ambiguous faces or body silhouettes. The results showed a strong

aftereffect of adaptation, such that after prolonged exposure to strongly 'male' stimuli, participants categorized the target stimuli as more 'female', and vice versa. However, to date, we have not found strong evidence for asymmetric representation of 'male' compared to 'female', contrary to our original hypothesis. Evidence about the organisation of male/female face and body representations does not converge on whether they are symmetrical or asymmetrical.
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The effects of action-based predictions in early visual cortex

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Self-generated stimuli are often perceived as less intense and lead to less neural activity in sensory cortices. This suppression effect is thought to be due to predictions that are created using the efference copy, a copy of the motor command. It is still unclear where such action-based predictions originate. Furthermore, evidence for the effect of action on visual stimuli remains inconclusive. In this study, we investigate these issues using fMRI and both univariate and multivariate analyses. The experiment contained active trials, in which participants elicited the appearance of two sequential gratings by a button press, and passive trials, in which the gratings appeared automatically. After a tone cueing which button to press and predicting the orientation of the gratings, a preparatory phase started in which only a fixation dot was shown. At the end of this phase, the fixation dot briefly flashed red to indicate that the gratings would appear soon (passive condition) or that participants could now press the button to elicit the appearance of the gratings (active condition). Participants then had to perform an orientation discrimination task on the gratings. Self-triggered stimuli led to more activity in visual cortex than stimuli that were automatically presented. No significant differences were found in the preparatory phase. Multivariate analysis showed that the grating orientation could be decoded significantly above chance from early visual areas both during and prior to stimulus presentation. Decoding accuracies did not differ between active and passive conditions. These results suggest that for both conditions, sensory predictions are already formed prior to stimulus presentation and may be based on similar mechanisms. Nevertheless, action leads to enhanced visual activity during stimulus processing. We conclude that visual cortex anticipates expected visual stimuli and responds with enhanced BOLD amplitude if they appear as the consequence of one's own action.
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Neuronal evidence for fast semantic parafoveal previewing during natural visual exploration

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Research on visual cognition has historically required that observers keep the eyes centrally fixated, but in natural vision humans execute saccades every ~250 ms. As the oculomotor system needs ~100 ms to initiate and execute a saccade, this leaves ~150 ms to plan and execute the next saccade, while processing the fixated item. How fast and in which detail an object is parafoveally processed during natural viewing remains largely unknown. We had observers complete a visual exploration task while we measured magnetoencephalography (MEG) and eye-movements. Observers were presented with an array of natural images from different categories (animal, food, object), that were displayed in greyscale or colours. The array was presented twice, and observers identified which image changed between presentations. Multivariate pattern analysis was applied on the neural data to track the emergence of information about the visual features (greyscale vs colour) and semantic category (e.g. animal vs food) of foveal and parafoveal images. The classifier identified the feature of foveal and upcoming parafoveal images at 70 and 88 ms respectively, and the category of foveal and upcoming parafoveal images at 145 and 160 ms. Also, the feature and the category of past parafoveal images remained present in the brain data until ~230 ms after the saccade onset. We here provide electrophysiological evidence that feature and semantic information of parafoveal objects can be extracted already within ~150 ms, supporting the role of parafoveal previewing in the planning of the next saccade. These results also suggest that the construction of a visual scene involves the maintenance of past information combined with the current visual perception and the identification of the upcoming parafoveal visual object. In sum, our study allows us to characterize the temporal dynamics of foveal and parafoveal neuronal processing at the feature and semantic levels during natural viewing.

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The effect of expectation on illusory positional shifts in flash-lag and flash-grab illusions

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In the flash-lag illusion, a stationary flash presented physically aligned with the center of a moving object appears to lag behind the moving object. An opposite effect is observed when the moving object reverses its motion direction at the moment of the flash. In particular, the static stimulus is perceived as ahead of the moving object's initial motion direction. This effect is known as the flash-grab illusion. In principle, both effects can arise due to a perceived positional shift of the moving object, the static object, or both. Although the motion extrapolation theory explains both illusions through mechanisms centered on prediction and prediction updating, it remains unclear how expectations affect the strengths of these illusions. Comparing the perceived positional shifts of static and moving objects under certain (100%), expected (80%), uncertain (50%), and surprising (20%) conditions of the flash-lag and flash-grab illusory displays, we tested whether the influences of expectations on moving and static objects are comparable for these motion illusions. Results revealed that the effect of expectation on the perceived positional shifts of the static and moving objects differed significantly between

the flash-lag and flash-grab illusory displays. The shift in the perceived position of the static object was greater when the flash-grab display was expected rather than surprising. Contrarily, expectations had no effect on the perceived position of the static object in the flash-lag display. Nonetheless, the moving object was perceived as shifted in the direction of expected motion in both flash-lag and flash-grab display conditions. We conclude that the illusory perceived shifts in the stationary flash and moving stimulus positions might share similar underlying mechanisms in the flash-grab but not in the flash-lag illusion. The disparities observed between two illusions could be attributed to distinct predictive processes occurring at different levels of the visual hierarchy.

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Contradictory illusions with striped objects

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A square with horizontal stripes appears taller than an identical square with vertical stripes (Helmholtz square illusion). However, there exists a widely held belief that a dress with vertical stripes makes you appear thinner and taller. This is directly opposite to the Helmholtz illusion. Most psychophysical studies have conformed to Helmholtz illusion. Still, there are some opposite findings too. In this study, I explore whether the contradictory results could be explained by stimulus presentation conditions. Cartoon figures (approximate size 1.5 × 3 deg), with varied height/width ratio and with different stripes (vertical, horizontal, and no stripes) were used as stimuli. In a two-interval forced choice experiment, observers had to indicate which of the two figures appeared fatter. Two presentation conditions were used: central vision (600 ms), and peripheral vision (4 deg eccentricity, 120 ms). The results of seven observers show a considerable interpersonal variability. However, there was a reliable difference between the two presentation conditions. With central presentation, observers tended to indicate a figure with vertical stripes as fatter; with peripheral presentation, one with horizontal stripes appeared fatter. The results suggest that differences between central vs peripheral vision could explain the contradictory illusions with striped objects.

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The visual system explicitly represents feature distributions!

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When explicitly asked to, observers cannot report skewness, kurtosis, or distributional shape of feature ensembles. This has been used to argue that the visual system does not have explicit access to distributional characteristics beyond mean and variance. However, indirect measures (e.g., visual search reaction times) have shown that these characteristics can be represented implicitly. Importantly, implicit paradigms probe only one value from the distribution in each trial and integrate multiple responses to recreate the distribution, whereas explicit tests involve reports of the whole distribution, requiring a more precise representation. We introduce a new experimental paradigm to address this discrepancy. Observers (N=10) were presented with 36 colored circles from Gaussian, uniform, or bimodal distributions for 800ms and then reported the frequency of a randomly chosen color using a slider. Trials with different distribution types and mean colors were intermixed. Results. The distribution of the averaged ratings (both aggregated and separate for each observer) followed the shape of the presented distribution. Segmented regressions showed significant break-points corresponding to each distributional type: e.g., a bimodal rating distribution had a break-point separating positive and negative slopes before and after one of the peaks. We developed a computational model that samples 1-36 circles with added noise, estimates the number of tested color circles in a sample, extrapolates the estimate to 36 circles, and gives the frequency response. The model best predicted observers' data when the sample size was close to all the presented circles. Thus, observers integrate information from many objects, their successful performance cannot be explained by the sampling of a few circles. Our new paradigm reveals that after brief exposure to a color set, observers accurately represent the relative frequencies of individual colors, meaning that they have reliable explicit access to the ensemble feature distribution.

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Insights From Eye Blinks into Cognitive Processes

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Behavioral differences in speed and accuracy between reading familiar and unfamiliar words are well-established in the empirical literature. However, these standard measures of skill proficiency are limited in their ability to capture the moment-to-moment processing involved in visual word recognition. In the present study, the effect of word familiarity was initially investigated using an eye blink rate among adults and children. The probability of eye blinking was higher for familiar (real) words than for unfamiliar (pseudo)words. This counterintuitive pattern of results suggests that the processing of unfamiliar (pseudo)words is more demanding and perhaps less rewarding than the processing of familiar (real) words, as previously observed in both behavioral and pupillometry data. Our findings suggest that the measurement of eye blinks might shed new light on the cognitive processes involved in visual word recognition and other domains of human cognition.

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Prior knowledge sharpens contrast perception: scene-object congruency modulates object detection

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Research have shown that prior knowledge facilitates information processing by sharpening the representation of expected objects, however, no previous study investigaged whether prior knowledge of a scene could affect perception of object contrast and how scene-object congruency modulates the detection of object. Here we examined these questions by briefly presenting two otherwise identical scene pictures except that one of the pictures contained an additional object. The perceptual contrast of object against the scene was manipulated across trials and participants needed to identify the picture that contained the additional object. In Experiment 1, we found that compared to meaningless backgrounds (random mondrain picture), participants were able to detect the target objects with lower contrasts in meaningful scenes. Experiment 2 confirmed this result by using as scrambled orginal scenes and upside-down orginal scenes as meaningless backgrounds. In other words, lower contrast was required to detect the object in the meaningful scenes than in meaningless scenes with the same physical properties. Experiment 3 extended this finding by showing that even with meaningful scenes, lower contrast was required to detect an object congruent with the scene (matched scene, e.g, detecting a cushion on a couch) than to detect an object incongruent with the scene (unmatched scene, e.g, detecting a windmill on a couch). These results suggest that the knowledge provided by a scene is essential in facilitating object perception, and high-level scene representations interact with early visual perception such as contrast, optimizing task performance for the current perceptual context.
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Intuitive visuomotor control of grip force in a (simulated) body-powered prosthesis?

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In normal visually guided grasping we can pick up even delicate objects without conscious effort. Ideally, control of body-powered prostheses (the most common type) would be similarly intuitive. This requires an accurate internal model relating arm-and-shoulder movements to prosthesis movements and grip force. Sprung-closed prostheses require input force to open, whereas sprung-open devices require force to close. Although sprung-closed devices can passively hold objects, they also reverse the normal, long-established relationship between muscle and grip force (reducing grip force requires inputting more muscle force and vice versa), which could make them fundamentally less suited to intuitive visuomotor control. We investigated this by examining grasping in healthy controls (N=20) using a simulated prosthesis—a cable-operated prehensor, worn on the forearm, and modelled on conventional body-powered prostheses. The prehensor was switchable between sprung-open and sprung-closed actuation, holding all other aspects constant. Participants reached for clothes-peg-like objects, which held a pin that was dropped if the object was grasped too hard. Successful movements therefore required grasping within a grip-force 'window' (which varied between objects), avoiding dropping either the object (insufficient force) or the pin (excessive force). Overall error rates were similar across the two prehensor actuation modes (and much higher than hand grasping). The pattern of force errors varied, however: in sprung-open mode most errors were due to excessive grip force, whereas in sprung-closed mode errors were more evenly distributed, with slightly more errors caused by insufficient grip force. Our results suggests that visuomotor control of grip force in sprung-closed prehensors is not overall more unintuitive than sprung-open devices. Interestingly, the different pattern of errors across actuation mode both correspond to a tendency to input too much force into the device. Our data suggest that the optimal actuation mode may not be a general device property but may instead be task-dependent.
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The Effect of Action on Visual False Percepts

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Hallucinations are commonly defined as the perception of sensory information despite the lack of corresponding sensory input. This phenomenon is a primary symptom of schizophrenia, however the mechanisms underlying hallucinations remain unclear. Hallucination-like experiences can be studied in signal detection tasks, in which participants have to detect signals in noise. Indeed, patients with schizophrenia report more false alarms than healthy controls, suggesting a general perceptual deficit. Another proposed mechanism underlying hallucinations is the disruption of efference copy signaling. The efference copy is a copy of the motor command, which is used to anticipate the sensory consequences of self-generated actions. These predictions usually lead to perceptual and neural suppression of the sensory action outcomes. Patients with schizophrenia show less suppression of self-generated stimuli than healthy controls. As such, it has been suggested that dysfunctional efference copy mechanisms are the source of hallucinations in schizophrenia. It is still unclear whether psychotic symptoms can be attributed to aberrant efference copy mechanisms, or to dysfunctional predictive mechanisms in general. To investigate this question, this study employed a signal-detection task with gratings obscured in dynamic noise under both active (self-generated) and passive (externally generated) conditions. Furthermore, participants filled out questionnaires testing for hallucination-proneness. Preliminary results showed a significant increase in false alarm rates in the active condition as compared to the passive condition, presumably driven by the significantly decreased response bias in the active condition, while d' did not differ between conditions. This suggests that action can lead to increased false alarms through overweighting priors in internal models, instead of through changing perceptual sensitivity. Ongoing analyses will test how this effect relates to hallucination-proneness.

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Integration of Visual and Tactile Information in Perception of Motion: Insights from a Multisensory Study

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The perception of motion is prominently focused on exploring similarities between vision and touch. This involves both system's ability to analyze spatiotemporal information to discern directions and orientations of stimuli. Indeed, literature has shown that the perceived direction of a moving plaid is influenced by the orientation of its constituent gratings in both vision and touch, where spatial information is processed analogous to the visual system. The present study aimed to investigate whether the presentation of two moving gratings, one presented visually and one tactually, leads to the integration of both into a unified perception and whether the different directions assumed by these gratings can influence this perception. The experiment included three conditions: unimodal visual, unimodal tactile, and bimodal synchronous visuo-tactile. During the experiment, participants faced RoMAT, a robot designed for investigating perception in multisensory motion tasks. RoMAT contains two physical rotating wheels that can be perceived visually and/or tactually. Participants were then required to assess the movement's direction of the perceived wheels: in the visuo-tactile condition, they were requested to evaluate the direction of the tactile wheel. The directions of movement were randomly selected from -22°, 0°, and 22° for each trial. In the multisensory condition, both visual and tactile wheels moved in the same direction during congruent trials, whereas they moved in different directions during multisensory incongruent trials. Results indicated that the visual stimuli modulated the perception of the tactile one. Notably, when visual and tactile stimuli had equal weights, participants' integration patterns aligned with the Maximum Likelihood Estimation model. Conversely, this pattern of integration did not hold for conditions in which visual and tactile inputs had differing weights. These results support that similar supramodal mechanisms are shared for visual and visual-tactile motion direction mechanisms.

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Top-down and bottom-up attentional guidance in different search task types

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A salient but irrelevant distractor captures attention in a bottom-up way when target characteristics are not predictable – a singleton search task. However, the distractor is ignored due to top-down control when the target feature value is consistent – a feature search task. It is unclear what would be preferred when experimental conditions allow for both strategies or force participants to switch between them. We developed tasks that ensures such conditions hoping to resolve theoretical issues. Participants (138 in total) were shown a search set with 1 target shape and 4 distractor shapes (one of them with salient color in 50% of trials). We tested attentional capture by distractor in: (E1) feature search task, (E2) singleton search task with unpredictable target shape, (E3) task with predictable shape singleton target and an instruction to search for shape singleton, (E4) task with predictable shape singleton target, but instruction to search for predefined shape, (E5) mixed task with singleton target in half of the trials and nonsingleton target in the other half. There was no capture by distractor in Experiments 1 and 5. But, distractor presence slowed RTs in all the tasks with singleton target status during the whole experiment, even if the instruction encouraged a top-down strategy (E2: $t(26) = 7.37$, $p < .00$; E3: $t(26) = 6.70$, $p < .001$; E4: $t(26) = 2.69$, $p = .012$). Our research showed that in the task with a singleton target, participants direct attention in a bottom-up fashion, resulting in attentional capture by irrelevant salient stimuli. In a task with a predefined target feature value, attention is guided by the top-down target template, which allows for the inhibition of irrelevant signals. We conclude that the bottom-up strategy is the default strategy, while the top-down strategy is preferred only to even costlier switching between strategies.

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Expectation is Insufficient: Assimilative Serial Dependence May Require Perceptual Information

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The perception of orientation is subject to assimilative serial dependence, wherein the reported orientation of a stimulus is biased to resemble the reported orientation of a stimulus presented in a similar location in the recent past. Serial dependence has been reported to orientations that are merely imagined by participants (Sheehan et al., 2022), as well as to decisions made about orientation in the absence of any visual input (Pascucci et al., 2019). These findings question the perceptual nature of serial dependence as they suggest visual input may not be necessary for the bias to occur. In two experiments, we cued participants to expect either a leftward- or rightward-tilted Gabor stimulus (Experiment 1, n = 25) or a horizontal or vertical Gabor stimulus (Experiment 2, n = 25) then presented either the cued inducer stimulus or noise alone. Participants reported which stimulus, if any, they saw. We then presented a second oriented Gabor stimulus and asked participants to rotate an on-screen pointer to match its orientation. We found that adjustment responses were skewed towards the orientations of inducer stimuli when they appeared, indicating serial dependence, but observed no serial dependence when participants were cued to expect a specific inducer stimulus but instead saw noise alone. Expecting a stimulus, or preparing to make a response to that stimulus, is not sufficient to induce serial dependence. Our findings suggest perceptual information is still important in serial dependence as it may be necessary to induce or enhance this bias.

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Age-related changes in automatic audiovisual speech processing in the McGurk effect

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Visual lip movements can change phonetic perception, even if they are rendered perceptually invisible (Teramoto & Ernst, 2023, Sci Rep), suggesting that visual information is automatically integrated with auditory speech information. This study investigated the age-related changes in automatic audiovisual speech processing in the McGurk effect using a continuous flash suppression (CFS) technique. Twenty-four young adults (21.04±1.73 years; age range: 19-28 years) and twenty-five older adults (75.56±3.73 years; age range: 71-85 years)

participated, watching videos of a person vocalising one of three syllables: “Ba”, “Da”, or “Ga”. Both the with-CFS and without-CFS conditions included audiovisual (AV) and audio-only set-ups. In the AV condition, AV-incongruent, McGurk trials (A: Ba, V: Ga), and AV-congruent trials (AV: Ba, Da, Ga) were conducted. Results showed that McGurk effects in the with-CFS condition occurred solely for young adults, whereas both groups exhibited similar effects in the without-CFS condition. Further analysis of individual differences in older adults revealed that the magnitude of the invisible McGurk effect positively correlated with indices of fluid intelligence such as working memory (letter number sequencing) and processing speed (coding). It has been reported that older adults exhibit good performance in automatic processing, but deteriorated performance in conscious, effortful processing. However, results suggest that automatic processing also declines, at least in audiovisual speech processing, which may, in turn, reduce conscious processing capacity in older adults.
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Reward enables learning of a salient but task-irrelevant visual feature through representation plasticity in V1

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Pairing external reward (water or money) can induce visual perceptual learning (VPL) of the paired visual feature when the feature is suprathreshold and salient. To examine reward-induced VPL and its underlying neural mechanisms, we trained two groups of participants (i.e., the Reward and the Control group) on a task-irrelevant stimulus feature presented as a Gabor patch in upper left or lower right quadrant over five days. The brain activation patterns of the Reward group were measured with fMRI before and after training. The Gabor patch was tilted either 2.5^{o} clockwise or counterclockwise of vertical and had one of six contrast levels (0.01 to 0.1). Participants performed a contrast categorization task by responding (2-AFC) whether the Gabor patch belonged to the high or low contrast group. The stimulus orientation offset from vertical remained salient but task irrelevant throughout training. However, in the Reward group (n = 16), a monetary reward was paired with one of the orientations (paired orientation) with 80% probability in one of the two stimulated quadrants (the trained quadrant). Participants were instructed that the reward was provided based on their central fixation performance (monitored with eyetracking). No reward was provided for the Control group (n = 5). Before and after training, participants performed an orientation discrimination task for Gabor patches with 6 different contrast levels presented in either of the quadrants. We found performance improvement for the paired orientation in both the trained and untrained quadrants in the Reward group. Meanwhile, we found enhanced decoding accuracy of the two orientations exclusively in V1 of the visual cortices. There was no performance change for the Control group. Our results suggest that external reward can enable VPL of a salient and suprathreshold visual feature through representational plasticity in the early visual cortex.
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Oscillatory and aperiodic mechanisms underlying domain-general attentional control

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Human cognition relies on a combination of domain-general and specialised neural mechanisms. While fMRI studies have identified a set of frontoparietal regions in supporting domain-general attentional control, it is less clear whether there are corresponding domain-general oscillatory or aperiodic processes supporting different types of cognitive activity. In this study, we recorded neural signals using combined MEG/EEG when participants were doing three cognitive tasks (working memory task, switching task, and multi-source interference task) with different contents (alphanumeric vs. colour stimuli) and demands (easy vs. hard). After separating the oscillatory and the aperiodic components using irregular resampling auto-spectral analysis, we used multivariate pattern analysis (MVPA) to decode task demand (easy vs. hard) for each subtask. We found that both oscillatory power (in theta, alpha, and beta bands) and aperiodic components (broadband power, slopes, and intercepts) could decode task demand for all six subtasks. Source estimation suggested distinct spatial bases for the different demand-related oscillatory and aperiodic components. For the demand-related oscillatory components, their spatial patterns are relatively focal, with mid-frontal regions for theta, occipital regions for alpha, and lateral-frontal regions for beta. In contrast, the demand-related aperiodic components showed distributed patterns across the brain, partially overlapping with the domain-general frontoparietal network. Our findings suggest the existence of a suite of oscillatory and aperiodic neural mechanisms, each with distinct spatial profiles, that support domain-general attentional control across multiple tasks.

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Effect of Distance on Visual-Haptic Integration in Thickness Perception

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This study investigated the effect of distance, a previously underexplored factor, on the weighting of sensory modalities during visuo-haptic integration. Participants (N = 30, 15 per task) engaged in two tasks: one involving the haptic judgment of object thickness by grasping a 3D-printed rod, and the other involving the visual judgment of object thickness by observing a virtual rod using a head-mounted display. For both tasks, standard stimuli (16 mm in diameter) were presented either as haptic-only or visual-only stimuli, followed by comparison stimuli (ranging from 13 to 19 mm), which integrated visual or haptic stimuli that were either increased or decreased by 10%. Tasks were conducted at three distances (200, 325, and 450 mm) to examine the effects of distance on points of subjective equality (PSE) relative to the standard stimuli. Modality weights were calculated from PSE in the ±10% conditions. Results showed that in the haptic judgment task, changes in visual stimuli and the effect of distance did not significantly affect PSE. However, in the visual judgment task, changes in haptic stimuli significantly affected PSE, with the weighting of haptic information varying significantly

with distance. Intriguingly, distance effects differed between the +10% and -10% conditions: haptic stimulus weight decreased with distance in the +10% condition but increased in the -10% condition. These findings suggest that haptic information, independent of distance, tends to dominate over visual information, which varies with retinal image changes due to distance, at least when using virtual visual stimuli. Furthermore, the variation in weighting with distance in the visual judgment task depends on whether the visual or haptic size is relatively thicker. This suggests that visual reliability may decrease when, despite expected reductions in retinal images with distance, haptic input like the -10% condition causes visual inputs to become relatively larger.
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Assessing the relationship between central visual field loss, physical activity, and cognitive function

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Macular degeneration results in the progressive loss of central vision and is the leading cause of blindness in the developed world. The loss of central vision affects performance of a variety of activities of daily living, both limiting high acuity tasks like reading and increasing isolation due to loss of mobility and decreases in physical and social activity. These outcomes are known to affect healthy aging and can be associated with accelerated cognitive decline. Here, we explore how cognitive and physical changes in macular degeneration compare with age-matched sighted controls. Data were collected from participants with macular degeneration and age-matched controls in both the United States and United Kingdom. Cognitive function was assessed using the Montreal Cognitive Assessment validated for visually impaired populations, the MoCA-Blind. Physical and lifestyle activity levels were evaluated using several measures, including the Timed Up-and-Go functional balance instrument and/or the augmented Victoria Longitudinal Study activities questionnaire. Information about the nature and extent of visual impairment was also collected. Preliminary findings reveal that overall average MoCA-Blind scores were significantly lower in the macular degeneration group compared with sighted controls. MoCA-Blind scores were positively correlated with physical and lifestyle activity levels as assessed by the Victoria Longitudinal Study activities questionnaire in both groups, regardless of visual status. However, MoCA-Blind scores did not correlate significantly with scores on the Timed Up-and-Go test after controlling for age. Understanding the consequences of macular degeneration beyond the eye is important in this ageing population; exploring relationships between clinical vision measures, physical and lifestyle activity and cognitive function may help identify patient needs, effective interventions and advance research exploring comorbidities between age-related visual impairment and other age-related disorders leading to cognitive decline.

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Influence of stimulus speed and individual differences on perception of visually-induced vection and motion sickness

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Moving visual stimuli can elicit the sensation of self-motion in the absence of actual physical movement (vection) and may also cause motion sickness-like sensations such as nausea, dizziness, or fatigue (visually induced motion sickness, VIMS). Factors such as optical flow have been discussed to contribute to both vection and VIMS. The aim of the current study was to further investigate stimulus-based (i.e., speed) and individual-differences factors (i.e., visual dependence, anxiety, depersonalization) relevant for vection and VIMS. Thirty-four participants (20 F, age = 19 to 44 years old) viewed a visual stimulus of alternating black-and-white vertical bars moving horizontally across three adjacent monitors. Stimulus speed was varied (fast vs. slow) and each stimulus was presented 40 times. Vection onset time, duration, and intensity were recorded for each trial. Levels of visual dependence (i.e., tendency to rely more on visual or non-visual cues for spatial orientation), trait and state anxiety, and depersonalization (i.e., tendency to experience out-of-body sensations) were reported prior to stimulus exposure using subjective measures. Results showed that vection duration, intensity, and onset time varied significantly depending on stimulus speed, with faster-moving stimuli evoking longer lasting and more intense vection responses with shorter onset time. A significant correlation was found between trait anxiety and vection intensity (r = .39) in the fast-moving condition, suggesting that higher trait anxiety was associated with more intense vection. Only weak correlations were found between all other individual-differences factors and vection intensity, duration, onset time (ranging from r = -.12 to -.01, and r = .02 to .32), and VIMS (ranging from r = -.27 to -.03, and r = .04 to .28). Our findings suggest that trait anxiety may contribute to the perceived intensity of vection, whereas visual dependence, state anxiety, and depersonalization might not be highly relevant factors for vection or VIMS.

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Investigating local and configural shape processing with Steady-State Visual Evoked Potentials

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The perception of object shape underlies our ability to detect, recognize and manipulate objects. Both local (curvature) and non-local (configural) shape cues contribute, and recent work has used specialized stimuli, computational modelling, and behavioural methods to dissociate these contributions. Here we used high-density (128 channels) EEG to explore the cortical mechanisms involved in both local and configural shape perception. Object shape silhouettes were presented during passive viewing in a Steady-State Visual Evoked Potentials (SSVEPs) paradigm that allowed us to isolate differential brain processing between pairs of stimulus conditions. Our stimuli were natural animal shapes (upright or inverted) and synthetic maximum-entropy shapes progressively matching local curvature statistics of natural shapes, but without global (configural) regularities (Elder et al., 2018). Our findings (n = 32) reveal differential activity in occipital and temporal cortices emerging 170–280 msec post-stimulus, influenced by both local curvature and global configural shape. The local curvature statistics, particularly the variance, was found to have a clear effect on brain processing in visual cortex. However, even when local statistics are fully controlled, responses to natural animal shapes are still quite distinct from the curvature-matched

controls. Interestingly, the differential responses to natural animal shapes compared to curvature-matched controls is subject to an inversion effect, highlighting the potential influence of semantic and holistic processing on the measured responses. It is important to note, however, that inverted animals still produce measurable differential responses compared to curvature-matched controls, suggesting that some configural properties survive the inversion. Future work will further explore what those properties are.
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Prioritized and non-prioritized features maintained in visual working memory differentially influence early visual processing

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Items held in visual working memory (VWM) can influence early visual processing by favoring visual input that matches the contents of memory. Recent studies have shown that memory items can have differing priorities within VWM depending on current task demands and that prioritized and non-prioritized memory items might rely on distinct storage mechanisms. Here, we aimed to investigate how the influence of VWM content on early visual processing depends on the priority state of the memory items. We utilized a double serial retro-cuing task to manipulate the priority of memory items and measured their influence on two distinct hallmarks of early visual processing—access to visual awareness and exogenous attention. This was done in three different experiments (total 72 participants) employing different perceptual tasks: the breaking continuous flash suppression task (Experiment 1), the attentional capture task (Experiment 2), and a visual search task (Experiment 3). Across all experiments, we found that participants could flexibly de-prioritize and re-prioritize items in VWM, thereby directly influencing the extent to which early visual processing is affected by VWM content. That is, stimuli matching prioritized VWM items gained access to consciousness faster and attracted attention more than stimuli matching non-prioritized VWM items. Interestingly, stimuli matching non-prioritized memory items also showed a perceptual advantage over stimuli that were unrelated to VWM content. When considering the experimental paradigms individually, non-prioritized memory items primarily accelerated conscious access of memory-matching stimuli (Experiment 1), while having a negligible influence on the allocation of attention (Experiments 2 and 3). These results suggest that both prioritized and non-prioritized memory items can influence early visual processing, with certain perceptual tasks showing greater sensitivity than others. This finding implies that non-prioritized memory items (akin to prioritized memory items) might be stored as sensory-like representations, thus allowing for interactions with concurrent visual input.
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Cognitive visual acuity testing in amblyopia – comparison of VEP- and P300-based acuity measures

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Background: Visual acuity (VA) is the fundamental test in the clinical routine to determine the integrity of visual function. Typically, the measurement depends on subjective responses although this is unreliable in certain conditions, e.g., children and uncooperative individuals. Visual evoked potential (VEP)-based objective measurement of VA generally overcomes this challenge, but it has limitations, e.g., VA overestimation in amblyopia. Purpose: This study aims to establish and compare objective VA testing with the cognitive component of the P300- event-related potential, in comparison to subjective VA (psychophysical) and VEP-based VA estimates in participants with amblyopia. Methods: The psychophysical, VEP-based VA, and P300-based VAs were determined for amblyopic and fellow eyes of 18 participants (aged 19-65 years) in a bicentric study. VEP-based VA is determined from the spatial frequency threshold derived from occipital cortex pattern-pulse responses to check-sizes ranging between 0.048° to 8.95°. The P300 responses were elicited by presenting visual oddball sequences to circular optotypes. The threshold was estimated from the sigmoid function of optotype gap size versus P300-amplitude from the parietal region (Pz). The mean VA values [logMAR] were compared between methods for the amblyopic eyes. Results: P300-based and psychophysical VA did not differ significantly (mean ± SD [logMAR], 0.01 ± 0.04, $p > 0.05$). In contrast, VEP-based VA of the amblyopic eyes was significantly better than the psychophysical VA by 0.18 ± 0.06, $p < 0.001$. Conclusion: In amblyopia, the results demonstrate a better match of psychophysical with P300-based VA than with VEP-based VA. Consequently, P300-based VA appears a valid objective alternative for VA estimation in amblyopia.
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Functional correlates of multistable perception can be seen in single participant ERPs

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When viewing an ambiguous figure like the Necker cube, our perception switches from one orientation to another despite unchanged sensory input. Previous studies have found two ERP components (P200 and P400) that increase in amplitude the less ambiguous the stimulus is ("ERP Uncertainty Effect"). Furthermore, the P200 seems to be linked to short-term memory (STM) related to the ambiguity

level of the previous stimulus and the P400 to the integration of this STM content with sensory evidence from the current stimulus. So far, these effects have only been investigated on the group level. In the present study, we investigated whether the functional patterns of the P200 and P400 amplitudes, observed in the group level can also be found in individual participants. Twenty-four participants viewed pairs of Necker lattices where the ambiguity of the first stimulus and second stimulus were varied, resulting in four conditions: (1) ambiguous/ambiguous, (2) ambiguous/disambiguated, (3) disambiguated/ambiguous, and (4) disambiguated/disambiguated. EEG recordings of the second lattice were analyzed using machine learning classification algorithms trained to compare P200 and P400 ERP peaks across conditions on the level of individual participants. Evaluation was done using the leave-one-out-method. Results indicate that using a model related to STM storage (P200) and integration function (P400) as classification criterion for our EEG analysis revealed classification accuracies of 79% at the Pz electrode. In most EEG studies it is critical to infer from group level results to data from individual participants. The results from the current study suggest that the functional attribution of the P200 and P400 amplitude modulations may allow for such inferences. This makes our paradigm interesting for current predictive coding approaches to visual perception. In future studies, these individual markers could be used in patients with temporal integration impairments, like schizophrenia and autism.
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Top-down driven hallucinations increase with age

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Visual hallucinations are associated with many states of disease including schizophrenia, Parkinson's disease, Alzheimer's disease, epilepsy and vision impairment. Whilst many of these conditions are particularly prevalent in older adults, hallucinations tend to be reported more frequently among younger adults, giving rise to an apparent contradiction. Potentially, older individuals may retrospectively under-report hallucinations due to stigma. To resolve this paradox, we developed a novel approach to measuring hallucinatory proneness by inducing hallucinations experimentally using two methods: a relatively bottom-up driven, high-frequency visual flicker ('Ganzflicker') and a relatively top-down driven technique, relying on perceptual deprivation (Ganzfeld). Hallucinatory experiences were quantified in real-time using button-presses, verbal prompts, and retrospective drawings. Our findings show that both the number of hallucinations and the total time spent hallucinating in the Ganzfeld increased with age. No such relationship was observed during the Ganzflicker. We suggest that age-related variations in hallucination susceptibility may be related to a variety of factors. Advancing age may lead to an increased weighting of previous knowledge and expectations due to accumulated experience. Concurrently, sensory deficits commonly arising with age may diminish the reliability of bottom-up sensory inputs, prompting individuals to rely more heavily on top-down cognitive processes. This shift in bottom-up and top-down dynamics is particularly pronounced when employing techniques that predominantly engage top-down processes to elicit hallucinations, such as the Ganzfeld, as opposed to those that elicit their hallucinatory effect primarily through bottom-up stimulation, like the Ganzflicker. These differences in hallucination susceptibility across the lifespan suggest that alterations in perceptual environments, such as Ganzfeld and Ganzflicker, might serve as diagnostic "stress tests" for conditions associated with visual hallucinations, including sensory loss, Parkinson's disease, and dementia.
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The Buffon-McDougall Visual Phenomenon and Its Implication for the Cortical Origin of Afterimages

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In 1774, Comte de Buffon described an intriguing phenomenon: One square can be seen as two squares in the afterimage of the primary scene. In 1786, Robert Darwin introduced Buffon's observation to the Royal Society and asserted that the effect was due to Buffon's exercising of free-fusion binocular viewing during the afterimage induction period ("Ocular spectra", p.341). This phenomenon can easily be seen by anyone who has normal binocular vision and is experienced in free-fusion binocular viewing: Let such a viewer look at a red square (e.g., 2 cm each side and viewed from a distance of 50 cm) on a white background, diverge their two eyes to focus on an imaginary depth plane either in front or behind the real background, and they will see two red squares: one from each eye; stay in this viewing condition for 30 seconds, move their gaze onto a white background, return their two eyes to the normal binocular viewing condition, and they will see two cyan-colored afterimages. In 1901, William McDougall discovered a variant of this phenomenon: With free-fusion binocular viewing, two squares can be induced into three afterimages with some binocular rivalry occurring in the middle one ("New observations, Part I", p.61). As Buffon and McDougall discovered two variants of this phenomenon independently, I propose that this phenomenon be referred to as the Buffon-McDougall phenomenon. Now I demonstrate an important implication of this phenomenon: A critical aspect of this phenomenon is that after the afterimage induction period when the viewer's two eyes return to their normal binocular viewing condition, the two afterimages still remain separate in their own locations—apparently, the visual system has "memorized" the relative positions of the two afterimages. This memory must have happened at a binocular stage; therefore, afterimages must be cortical in origin.

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Humans use mental simulation and eye movements to facilitate perceptual decision-making

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A fundamental property of the human brain is the ability to use mental simulation to make predictions about the behaviour and appearance of objects. For example, in mental rotation, humans can visualize object rotations, and compare predicted object appearance across different simulated viewpoints. Due to non-uniformities in object viewpoint perception, the amount of visual change that occurs as an object rotates can differ depending on both the object and the viewpoint it is seen from. This study investigated how humans use mental simulation to solve a perceptual decision-making task (judging non-uniformities in object viewpoint perception), and how they sample visual information via eye movements to facilitate this mental simulation. Twenty participants were presented with the most and least discriminable viewpoints of an object, as predicted by an optical-flow model. They had to choose which viewpoint they would prefer to use in a subsequent discrimination task that was easier if they chose the most discriminable viewpoint. We predicted that to choose the easier viewpoint, participants would have to simulate each viewpoint's appearance if it rotated slightly, and they should look at specific informative regions on the object (model-predicted regions that would undergo the most displacement with rotation) to facilitate this mental simulation. Results show that 1) participants could infer and choose which viewpoint was easier for the discrimination task; 2) they tended to look more frequently at informative regions on the objects; and 3) participants who looked at more informative regions chose the easier viewpoint more often.
Our results suggest that to perform fine-grained mental simulation people need to direct their gaze to informative points of an object to simulate how its appearance might change. They also show that our internal representations and simulations are driven by the proximal information that is gathered using precisely planned eye movements.

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Apparent motion may trigger colour filling-in

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We present an illusion in which apparent motion appears to trigger colour filling-in. The illusion consists of two alternating displays of coloured discs. Display 1 shows rows of equally sized purple discs. Display 2 shows rows of alternating pink and blue discs of the same size as Display 1. The pink and blue discs overlap partially, with the overlapping areas being the same purple as the purple discs in Display 1. There are two versions of Display 2. In one version (Display 2A) the pink discs are in the same position as the purple disc of Display 1. In the other version (Display 2B), the blue discs are in the same position as the purple discs of Display 1. When the displays alternate (i.e. Display 1 and Display 2A, vs. Display 1 and Display 2B), the purple discs appear to jump sideways, apparently suppressing the colour of the 'underlying' blue discs (Display 2A) or pink discs (Display 2B) and filling them with the colour purple. This leads to the perception of a predominantly purple/pink colour impression for Display 2A and a purple/blue colour impression for Display 2B. The illusory displays were shown during the demo night at ECVP 2022 and largely confirmed by the audience. A recent experiment with 30 participants confirmed our initial observation, but also revealed some interesting individual differences. We will discuss possible underlying mechanisms.

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Through the Lens of a Colour Blind: Exploring impacts of simulated colour blindness on schoolchildren

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With an increase in school resources relying on colour cues, children with colour vision deficiencies (CVD) are increasingly impacted academically and emotionally. Yet the awareness of the problem is lagging, with no mandatory screening for CVD or adjustments to support affected children. Is it time to re-evaluate current screening policies? Here, we induced CVD in colour-normal children to investigate whether underperformance on a typical task using colour, influences children's levels of frustration and confidence. Using a repeated measures design,181 schoolchildren (85 males, 6-11 years) with normal colour vision completed two colour-by-number worksheets with and without 'Variantor Dichromatic Spectacles' in their school environment. Counterbalancing was applied and feedback was given regarding performance. Children rated their frustration and confidence on 5-point Likert scales after each task. As expected, children achieved lower scores during the Variantor condition (with Mdn = 4.00, without Mdn = 6.00) ($z = -10.56$, $p < .001$, $r = -0.56$) and took longer (with = 5.52 minutes, without = 3.80 minutes) to complete the worksheet. Wilcoxon Signed Ranks tests revealed Variantor spectacles induced significantly higher levels of frustration (with Mdn = 3.00, without (Mdn = 1.00) ($z = -9.86$, $p < .001$, $r = -0.52$), and lower levels of confidence (with Mdn = 4.00, without Mdn = 5.00) ($z = -9.27$, $p < .001$, $r = -0.49$). Although our study used colour-normal children to test potential impacts of simulated CVD, results imply CVD can have negative consequences on children's levels of frustration and confidence on a single occasion. We suspect a lifetime of accumulated failures during colour-related tests can lead to poor outcomes in children's development of self-esteem. Our findings clearly add to the growing body of evidence suggesting children should be screened for CVD, so reasonable adjustments can be made to avoid potential detriments to their social-emotional development.

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Decoding emotional content of complex social scenes in the human brain and deep neural networks

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Humans can evaluate the emotional meaning of complex social interactions in real-life settings, but it is unclear how this assessment is achieved. Previous research suggested that the emotional content of images is represented in visual areas of the brain and captured by basic artificial intelligence (AI) models. However, they included simple images and these findings may not apply to complex scenes involving social interactions. Here, we prepared stimuli depicting social human interactions in emotionally loaded scene contexts, e.g. funerals. Across the full set the valence of the people in the scene was partially dissociated from the valence of the scene context, e.g. people laughing at a funeral. Neuroimaging (fMRI) responses showed that visual areas represent the emotional valence of the scene

context and not the valence of people in the scene and category-selective areas are not the main regions for coding valence. Instead, category-selective areas respond to properties of faces and scene elements related to the category preferences of these regions. Neural responses selective to the valence of people in the scene and the image as a whole are only generalized across images in the association and frontal cortex. AI responses showed existing models for image valence processing rely mostly on the valence of the scene context while advanced multi-modal AI models that integrate text and vision can partially capture the valence of the social interactions on top of the valence of the scene context. Neuroimaging and behavioral mouse-tracking experiments disclose different processes for perceiving social stimuli with (mis)match between the valence of the scene context and the valence of people in the scene and this two-fold mechanism is a challenge for AI in modeling social perception. Our findings indicate that understanding complex social interactions requires advanced cognitive processes that go beyond the coding of visual features.
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Binocular Rivalry Priming Reveals the Dynamics of Mental Imagery

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There has been a recent surge in interest surrounding imagery vividness extremes, such as aphantasia and hyperphantasia, driven by the prospect of gaining deeper insights into the brain as a predictive instrument, where memory traces are reconstructed as simulations of future events. However, reliable methods for assessing imagery strength remain elusive. Here we employ a no-report version of binocular rivalry (BR) priming to avoid the issues of subjectivity and response bias. Participants view rivalrous gratings moving in opposite directions while their eye-movements are registered. Perceived appearance of the stimulus and its spontaneous reversals are accompanied by shifts in oculomotor behaviour, namely, the smooth pursuit phase of optokinetic nystagmus (OKN) corresponds to the dominant direction of motion, therefore, no responses are required in the form of button presses. Smooth pursuit segments are identified, interpolated where necessary, and joined probabilistically into a continuous record of cumulative smooth pursuit (Aleshin et al. 2019). Prior to each BR-OKN trial, participants are primed either with a real stimulus cueing them towards a specific motion direction or through various internal prime conditions. In the visual internal prime condition (VIS), participants visually imagine the grating moving in a particular direction, while in the verbal internal prime condition (PROP), they repeat a proposition regarding the direction of movement during the priming period. Hyperphantasic participants exhibit significant priming after VIS, and a marginal trend towards priming after PROP. Conversely, aphantasic participants demonstrate priming after PROP but not after VIS. Neurotypical participants, as determined by the Vividness of Mental Imagery Questionnaire, present a varied response pattern with most individuals displaying limited priming effects and no clear preference for either VIS or PROP. The no-report BR priming method not only offers a novel objective evaluation of mental imagery, but the results also suggest a potential trade-off between visual and abstract representations.
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Augmenting functional vision using automated tactile guidance

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We developed a tactile bracelet to haptically guide and enable the grasping of objects without vision. Our previous study shows that both blindfolded and blind people can distinguish between tactile signals and that their performance in a grasping task is comparable when guided by an experimenter with the use of auditory and tactile commands. Currently, we are aiming to fully automate the solution without affecting the participants' performance. The automated solution setup consists of object detection and hand-guiding heuristics. For the object detection component, we use two YOLOv5 networks trained on the COCO and EgoHands datasets to detect objects and hands, respectively. To enable targeting a specific instance of the object rather than a whole class we are utilizing the StrongSORT object tracking algorithm. Preliminary results from a pilot study conducted on blindfolded participants show the system's ability to effectively guide the hand to the selected target object placed on the shelf. Performance was similarly robust regardless of the object placement and hand initial position. Additional computations related to the processing of object detections and hand-guiding logic impacted the performance speed with a single frame from the camera processed for roughly 100ms. Nonetheless, smooth and precise guidance was still possible even under such conditions. Importantly, participants provided positive feedback about the usability of and their experience with the bracelet and several suggestions about potential improvements. Upon optimization of the current setup and the addition of the more precise distance estimation component, we plan to conduct further experiments testing the system's ability to perform in several different environments and conditions. Our end goal is to create a system that blind people can use independently without any need for human assistance, enhancing their autonomy and quality of life.
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Object tracking without objects: Perceiving persistence defined by pure change

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Object tracking seems to require objects: to identify a change in position over time, you must perceive the position of *something*—a shape, or at least a consistent visual feature. Here we show through vivid demonstrations and multiple experiments that this is not so: we reflexively perceive—and can reliably track—objects defined by *pure change*. In basic demonstrations, we showed observers

displays filled with hundreds of small crosses, arranged in a regular grid, with each individual cross oriented randomly. Certain crosses then suddenly changed orientations—one cross at a time, in a sequence from each cross to its neighbor, but never repeating the same orientations. Unlike typical displays, such animations have no objects with features that persist from moment to moment: every static frame simply contains an array of randomly-oriented crosses. And unlike motion-defined objects (e.g. with random-noise patches moving on a random-noise background), there is nothing consistent to track from frame to frame. Nevertheless, observers vividly perceive moving objects which persist across time due only to pure change. A series of experiments first showed that observers can readily detect such change-defined objects amidst carefully equated distractors—often with near-ceiling performance. Moreover, observers can even perform multiple-object tracking when all objects (both targets and distractors) are defined by pure change. We also generalized this phenomenon in several ways, showing that it also occurs when the changes themselves involve features (such as brightness) without local motion—and indeed even when different kinds of changes are haphazardly interleaved (e.g. with an orientation change to one cross followed by a brightness change to its neighbor, etc.). Thus change alone can fuel the perception of persisting objects—an ability that may be useful, e.g. when seeing the movement of a short animal through changes in the tall grass.

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Effects of top-down attention on audiovisual binocular rivalry

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Multisensory integration has been reported to modulate the visual awareness in binocular rivalry. In the previous audiovisual and olfactovisual studies, awareness of congruent stimuli was readily formed. These effects of multisensory integration, where integrated sensory information is more readily formed into consciousness, align with predictions from the Integrated Information Theory of consciousness (IIT). However, there remains the possibility that integrated sensory information is more attention-grabbing, then may consequently be formed into consciousness, as the Global Workspace Theory (GWT) predicts. The present study investigated the influence of top-down attention to the audiovisual congruent stimuli in the binocular rivalry. Random-dot kinematograms (RDKs) are presented to each eye and moved in the opposite direction. Different colors for the dots and background were presented to the left and right eyes. Auditory stimuli were presented that corresponded to the direction of movement presented in either eye. Participants were tasked with responding to the direction of dot motion, the color of the dots, or the color of the background, depending on the condition. The duration of periods during which either of the left or right stimuli was predominantly perceived was recorded and compared among the attending-motion, attending-dot color, and attending-background color conditions.

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Shape-specific chromatic adaptation precedes history biases in color perception

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Color percepts in delayed-matching tasks are biased towards recent stimulus history. When the stimulus set contains two distinct shapes that have partly overlapping color distributions, both attractive and repulsive biases are observed: in within-shape comparisons, color estimates are shifted towards the mean color, while in across-shape comparisons, color estimates are shifted away from the respective mean color. This result is not consistent with either a general or a shape-specific history bias but is instead qualitatively predicted by shape-specific adaptation to color range, followed by a common bias towards stimulus history. We present a quantitative formulation of this two-stage model, where the shapes are first subjected to adaptation to their respective color range, after which there is a general bias towards the central tendency of the adapted ranges (adaptation+central tendency bias or CTB). We fit the model to individual data from 46 observers across four experiments and compared the full model fits to models with only adaptation or only CTB. All observers showed both adaptation and CTB, CTB being stronger for most observers. The two effects were not correlated significantly across observers, indicating that they are subserved by separate mechanisms. For one of the experiments, we were able to assess the evolution of the two effects across two runs. This analysis showed that CTB developed quickly with no significant difference between runs (mixed effects model with run as fixed effect and observer as random effect, $F(1,19)=0.26, p=0.61$). Adaptation, on the other hand, developed more slowly and was significantly stronger in the second run ($F(1,19)=5.84$, $p=0.026$). History biases in color perception are not determined solely by the chromatic content of the stimulus ensemble. Adaptation to the shape-specific chromatic range occurs first for each distinct shape, and history biases operate on the adapted color percepts.

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Pre-stimulus alpha oscillations encode stimulus-specific visual predictions

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Predictions of future events have a major impact on how we process sensory signals. However, it remains unclear how the brain keeps predictions online in anticipation of future inputs. Here, we combined magnetoencephalography (MEG) and multivariate decoding techniques to investigate the content of perceptual predictions and their frequency characteristics. Participants were engaged in a shape discrimination task, while auditory cues predicted which specific shape would likely appear. Frequency analysis revealed significant oscillatory fluctuations of predicted shape representations in the pre-stimulus window in the alpha band (10-11 Hz). Furthermore, we found that this stimulus-specific alpha power was linked to expectation effects on shape discrimination. Our findings demonstrate that sensory predictions are embedded in pre-stimulus alpha oscillations and modulate subsequent perceptual performance, providing a neural mechanism through which the brain deploys perceptual predictions.

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Neural Dynamics of Part-Based Face Perception

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Faces, abundant in social cues, are vital in everyday life. Despite their ubiquitous presence, research on dynamic face perception often focuses on emotional contexts, leaving a gap in understanding the processing of non-emotional, dynamic facial information, particularly concerning the eyes and mouth. Here, we investigate the neural mechanisms involved in processing dynamic information from individual facial parts during face perception. Using muted grayscale videos of models vocalizing a text, we manipulated the presence of a blink and spatial layout (upright or inverted), while frequency-tagging the eyes and mouth at 6 Hz and 7.5 Hz, respectively. Two experiments were conducted, with steady-state visual evoked potentials recorded via EEG. In Experiment 1, participants judged temporal order (backward or forward) while fixating on a central cross, showing proficient performance ($d' > 0$). To minimize language comprehension effects, Experiment 2 employed an orthogonal task (all $d' > 0$). Topographic maps In Experiment 1 revealed a central-occipital focus for the eyes and a broader left lateral-occipital focus for the mouth, suggesting a general tendency for covertly attending the mouth region. Experiment 2 yielded similar results, albeit with diminished left lateralization of neural activation. Analysis of 6 occipital channels In Experiment 1 revealed a significant orientation effect consistent with existing literature ($p < .01$). Interestingly, attentional bias towards the mouth was absent in inverted faces, where a marginally significant blink effect in the occipital area was observed ($p = .05$). In both experiments, individuals prioritized cues from the mouth when viewing upright face videos presented forward or backward. This study enhances our understanding of dynamic face perception by underscoring the significance of dynamic part-based cues in shaping visual processing.
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The Feature Filtering Function from Consciousness to Working Memory

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Consciousness and working memory (WM) are two central topics in psychology and neuroscience. However, the debate on whether and how content in consciousness enters WM has persisted for decades. In this study, we investigate the feature filtering function from consciousness to working memory regarding a single fully attended stimulus with seven attributes, including location, size, color, tilt, letter case, numeric identity, and parity. We used the attribute amnesia paradigm by probing only one attribute of the stimulus in the first 43 trials, followed by a surprising probe of the memory of another attribute in the subsequent five trials. Firstly, we demonstrate how these seven attributes show different levels of availability in WM on the surprise trial (Experiment 1; N = 1344), revealing three feature filtering functions: spatial resolution, semantic advantage, and color asymmetry. To confirm that all attributes are indeed consciously experienced during stimulus display, we found that even the most forgotten attribute in WM, such as letter case, is available in iconic memory within 300 ms after the stimulus offset using a change detection task (Experiment 2; N = 96). Finally, different memory performances may be influenced by varying levels of attention allocated to each attribute (a pre-perceptual mechanism) or prioritization of encoding one attribute into WM leading to different levels of loss of the others (a post-perceptual mechanism). By replicating the patterns observed in Experiment 1 in a design where all attributes are equally task-relevant (Experiment 3; N = 128), we provide evidence for the post-perceptual mechanism while fully controlling the pre-perceptual mechanism. Our results offered not only strong evidence for consciousness overflowing WM but also revealing a two-system model of WM consolidation that is independent from attention: a fast-decaying sensory memory system and an advantaged semantic memory system.
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Kinematic Features Influencing Affective Responses to Bodily Motion in Shorinji-Kempo Martial Artists

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Bodily movement serves as a rich source of information. Performance artists leverage this expressiveness of bodily motion to evoke aesthetic responses in observers. Similarly, in martial arts scoring competitions, judges conduct affective evaluations of athletes' bodily movements across various affective dimensions. However, the perceptual mechanism underlying the formation of affective and aesthetic evaluations of bodily motion remains unclear. To address this gap, the present study investigated the relationship between kinematic features of bodily motion and its affective evaluations. Initially, we recorded the bodily motion of Shorinji-Kempo martial artists using 3D motion capture (mocap) technology. Subsequently, we generated point-light display animations (PLDs) based on these recordings. The primary phase of the study involved an online experiment where about 200 participants viewed these PLDs and provided affective evaluations of "strength," "beauty," "sharpness," and "intensity" using Likert scales. Kinematic features were extracted from the mocap data, and after standardizing both the subjective scores and kinematic features, we subjected the data to principal-component (PC) multiple regression to model the association between affective evaluations and kinematic features for each participant. The standardized coefficients were analyzed at the group level to identify the kinematic features associated with affective evaluation of bodily movement. The findings revealed that the four dimensions of affective evaluations were linked to largely shared, albeit slightly different sets of PCs. Further analysis indicated that acceleration played a significant role in all affective evaluations, contrary to the presumed insensitivity of the human visual system to acceleration information. These results suggest that the neural system forms affective evaluations of bodily movement by flexibly integrating multiple and subtle cues from kinematic features.

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Core neural dimensions of functionally selective areas in the human visual cortex

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Prior research has extensively documented functional selectivity for categories within visual cortical areas, primarily by contrasting neural responses to images from various categories. However, such categorical approaches are less suitable to capture the diversity of neural representations within these areas. Do category-selective areas encode holistic categories, or are they instead tuned to multifaceted features? To address this question, we employed non-negative matrix factorization (NMF) for analyzing human fMRI responses to natural images in face-, body-, and scene-selective areas, which uncovered a consistent set of interpretable neural dimensions across participants. These dimensions not only aligned with the areas' respective category preferences, but also revealed finer within-category distinctions, indicating selective tuning to diverse visual input features. Mapping these dimensions onto the cortical surface displayed both clustered and distributed topographies, which accounted for overlaps between areas. Our results suggest that category-selective areas show multifaceted feature tuning, challenging traditional views and highlighting the complex interplay of neural dimensions in encoding visual information.
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The influence of dimmed lighting conditions on naturalistic obstacle negotiation in young and older adults

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Falls due to slipping and tripping in older adults are a major public health concern, since over one third of adults aged over 65 experience falls annually. These incidents can lead to severe consequences for older adults such as lower quality of life, hospitalization and increased risk of death. The risk of falls escalates with age-related decline in the visual, vestibular, and somatosensory systems. Moreover, changes in natural gait patterns and risk of falls are influenced by the amount of ambient light within the immediate environment. Adaptive gait mechanisms vary with age. While young individuals can effectively modify their gait when visual information is limited (such as when lighting is dimmed or low), older adults are less able. This interaction between the visual and locomotor systems is especially evident during obstacle negotiation, reflecting an adaptation in movement strategies based on visual cues. This proposed study will investigate how different light conditions influence walking patterns and obstacle negotiation in young and older adults. Participants will walk along a track, on which obstacles will be projected, either prior to starting (predictable obstacles) or after they have started walking (unpredictable obstacles). Mobile EEG data will be collected during naturalistic walking to identify neural correlates of successful and unsuccessful obstacle negotiations. We predict that older adults will have reduced speed, shorter stride length, increased stride time and more obstacle negotiation errors relative to young adults, particularly in dimmed and dark lighting. Additionally, negotiating unpredicted obstacles in lower lighting conditions will involve greater proactive cognitive control (as indexed by frontal theta oscillations) relative to predictable obstacles, and obstacles presented in full ambient lighting. This will allow us to better understand how the visual environment places increased cognitive demands on older adults during real-world behaviours, and to design environments more effectively to minimise these demands.
Acknowledgements: Funder- Institute for Advanced Studies (University of Stirling).

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Hierarchical cortical entrainment orchestrates the multisensory processing of biological motion

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When observing others' behaviors, we continuously integrate their movements with the corresponding sounds to achieve efficient perception and develop adaptive responses. However, how human brains integrate these complex audiovisual cues based on their natural temporal correspondence remains unknown. Using electroencephalogram, we demonstrated that cortical oscillations entrained to hierarchical rhythmic structures (i.e., step cycle and gait cycle) in audiovisually congruent human walking movements and footstep sounds, and the strength of the entrainment effect was higher than that in the visual-only or auditory-only condition, indicating multisensory gains. Notably, the entrainment effects at different time scales exhibit distinct modes of multisensory integration, i.e., an additive integration effect at a basic-level integration window (step-cycle) and a super-additive multisensory enhancement at a higher-order temporal integration window (gait-cycle). Moreover, only the cortical tracking of higher-order rhythmic structures is specialized for the multisensory integration of human motion signals and correlates with individuals' autistic traits, suggesting its functional relevance to biological motion perception and social cognition. These findings unveil the multifaceted roles of entrained cortical activity in the multisensory perception of human motion, shedding light on how hierarchical cortical entrainment orchestrates the processing of complex, rhythmic stimuli in natural contexts.
Acknowledgements: This research was supported by grants from the Ministry of Science and Technology of China (STI2030-Major Projects 2021ZD0203800 and 2021ZD0204200), the National Natural Science Foundation of China (Nos. 32171059 and 31830037), the Interdisciplinary Innovation Team (JCTD-2021-06), the Youth Innovation Promotion Association of the Chinese Academy of Sciences, and the Fundamental Research Funds for the Central Universities.

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Beneath the Surface: Feature Synergy Improves Texture Segregation but not Shape Perception

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Simultaneous texture modulation in two feature dimensions improves detection and shape discrimination performance significantly more than expected from independent feature processing. However, the roots of this feature synergy effect remain unidentified. We investigated the predictive power of the low-level metric of contrast energy, which quantifies the average local energy at a given scale and orientation. Contrast energy proved to be a good predictor of feature synergy in the detection of both feature-modulated and feature-variability (bandwidth) modulated textures. Synergy was robustly predicted by mechanisms analogous to early visual processing, suggesting that saliency-based enhancement of figure-ground segregation plays a critical role in the psychophysical feature synergy effect. Extending our investigation beyond simple figure-ground segregation, we investigated the discrimination of complex shapes. Our results revealed an interesting asymmetry: While a strong synergy persisted for target detection over a wide sensitivity range, it decreased significantly for complex shape discrimination. This discrepancy remained evident even on a neutral saliency scale, where luminance contrast was cross-modally matched to the feature contrasts in orientation and spatial frequency used for shape discrimination. In addition, we investigated feature synergy for maximum feature differences between target and background, where perfect detection performance was achieved. Unexpectedly, the accuracy of shape discrimination for combined features fell short of perfection. This divergence highlights that increased target saliency alone is not sufficient to extract distinct shape representations from textured stimuli. In summary, our results indicate that feature synergy occurs during figure-ground segregation based on saliency, but that there is no additional synergy for extracting distinct shapes from textures.

Tuesday 27th August

Poster Session 3

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Searching for color with color-enhancing filters

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Notch filters can enhance color contrasts by selectively altering the light spectrum reaching the eye, and are similar in effect to wide gamut (narrowband) lighting. However, the conditions and tasks for which such filters improve color vision remain debated. We examined the impact of notch filtering for color-normal observers performing a naturalistic, visual-foraging task for a colored “fruit” on a dappled “foliage” background (McDermott et al. JOV 2010). Chromaticities on the display were calculated to simulate Munsell surfaces viewed under D65 lighting either with or without the filter, which was based on the transmittance of the Enchroma SuperX® glasses. These glasses amplify chromatic contrasts along a roughly magenta-lime axis by increasing colorimetric purity of some spectra, and are designed for use by normal trichromats. Mean luminance and chromaticity for the filtered and unfiltered images were equated by assuming von Kries adaptation to the average spectrum. Background ellipses varied along either the S-cone axis (typical of some foliage) or a blue-yellow axis (typical of panoramic natural scenes), while target colors were sampled from a wide range of hue angles and contrasts in cone-opponent space. The 0.5 degree target color was randomly positioned on the 11.6 by 20 degrees background, with reaction times measured for detecting the location (left/right). Nine color-normal observers completed 20 repetitions for each target/background condition, with the order of the filter condition counterbalanced and unknown to participants. Median reaction times decreased systematically with increasing distance of the target chromaticity from the background chromatic axis. However, for both backgrounds, overall search times for off-axis colors were faster with the simulated filters, with stronger enhancements for the blue-yellow background. These results demonstrate that color-enhancing filters can potentially improve performance on common everyday tasks, like visual search for color, particularly in specific colorful contexts.

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Visual encoding of social interactions in body-selective human brain regions

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Social vision studies of the human visual system have focused on the representation of individuals, identifying regions that contribute to the perception of single faces, bodies, and movements. More recent functional neuroimaging work has examined the encoding of interacting people, typically shown in highly schematized images or animations, revealing selective activity in the posterior superior temporal sulcus and in the extrastriate body area. Further, recent neurostimulation evidence demonstrates a causal role for the left extrastriate body area in encoding static images of facing dyads. Here we sought to further test whether the extrastriate body area is attuned to social interactions depicted in more naturalistic images. We performed new analyses of an open 7T fMRI data set in which 8 participants viewed thousands of images from the COCO image database. We analysed the responses to about 200 images that were seen by all participants and had 2 or more people depicted. We collected new behavioural ratings for each image on the extent to which it depicted social interaction. These were supplemented by a simple textual analysis of image labels from the COCO dataset. The number of people in each image was measured via subjective ratings and with a simple neural network object detection algorithm. Each image was also given a position coefficient describing the spatial distribution of people over the scene. These measures were all applied as regressors to explain observed responses to the images in the individually localised extrastriate body area of each participant. We found significant evidence for increasing responses in both hemispheres as a function of the extent of social interaction depicted, above and beyond the number of individuals per se. These findings confirm and extend evidence for a role of the extrastriate body area in representing social interactions in realistic images.
Acknowledgements: DAAD RISE Worldwide.

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Saccade kinematics and post-saccadic oscillations in retinitis pigmentosa and age-related macular degeneration

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Eye-movement studies in patients with visual field defects have mainly focused on exploration strategies rather than saccade kinematics. However, understanding how saccade trajectories adapt within these constraints is crucial. We compared saccade behavior in subjects with age-related macular degeneration (AMD, n=6) or retinitis pigmentosa (RP, n=5) to normal vision (NV, n=7) using a horizontal saccade task and pupil-based eye tracking. Visual deficits were assessed using Goldman perimetry (RP patients) or fundus autofluorescence imaging (AMD patients). We employed Macular Integrity Assessment (MAIA microperimetry) to identify eccentric fixation and determine each eye's preferred retinal locus, enabling precise mapping of binocular blind areas. We analyzed reaction times and target localization relative to the subjects' visual field defects. Additionally, we quantified the relationship between saccade amplitude, duration, and peak velocity, considering recent speed-accuracy trade-off theories in optimizing vision. In both patient groups, we observed deficits in reaction times and localization accuracy, along with alterations in saccade kinematics. Particularly in RP patients, saccades were slower and exhibited atypical velocity profiles, with the most significant impact seen when the target was within their blind field. Additionally, we observed distinct post-saccadic oscillations (PSOs), indicating compromised retinal image stability in AMD and RP patients. Using a damped oscillation model, we found larger PSO amplitudes, longer decay time constants, and lower frequencies in patients compared to controls. While PSO amplitude correlated positively with saccade deceleration across groups, other PSO parameters did not consistently correlate with saccade kinematics. We conclude that central and peripheral retinal damage influences the saccade main sequence, emphasizing the role of vision in planning saccade kinematics. Moreover, compromised post-saccadic fixation stability in AMD and RP patients is due to abnormal PSOs, indicating anatomical and neuronal variations affecting PSOs. These abnormalities underscore the challenges individuals with retinal pathology face in maintaining retinal image stability and visual acuity.
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Visual feedback codes during amodal completion and visual imagery

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Our study investigates the mechanisms of amodal completion and visual imagery, processes fundamental to our understanding of visual perception. Amodal completion entails the brain's ability to fill in missing parts of objects, while visual imagery allows for the creation of mental pictures without external input, both relying on internal feedback mechanisms. To further our understanding of these two mechanisms, we conducted a human 7T fMRI experiment utilizing natural scene images combined with a visual occlusion paradigm, allwoing for the isolation of feedback signals within a non-stimulated region of the V1 cortex. Twenty-eight healthy human participants attended the fMRI experiment. In the initial phase, participants were presented with trials of scene images for amodal completion, while on alternate trials they were tasked with mentally reconstructing the complete version of previously seen occluded images. In the subsequent phase of fMRI scanning, participants viewed the full scene image followed by trials requiring them to imagine the full image separately. We employed a multivoxel pattern analysis (MVPA) using a linear support vector machine approach and performed representational similarity analysis (RSA) on the fMRI data. The MVPA decoding results from the amodal completion condition reveal that the category information can be decoded in the occluded early visual areas, replicating our previous findings that non-stimulated early visual areas contain information about surrounding context. The RSA results comparing imagery based on amodal completion and imagery based on full perception indicate a dissimilarity, suggesting that visual imagery activity differs depending on whether it is based on image-specific memory or driven by contextual cues. Our findings underscore that feedback information utilised in amodal completion heavily relies on surrounding contextual information, whereas feedback information employed in imagery may instead draw upon stored prior knowledge in the brain, which can be updated by the feedforward information.

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Ideal population orientation coding in macaque V1 explored with a self-attention DNN model

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We have previously utilized two-photon calcium imaging to record the responses of V1 superficial-layer neurons to a Gabor stimulus at various orientations and spatial frequencies in awake, fixating macaques (Ju et al., 2021). Using these large datasets, here we explored ideal strategies of population orientation coding by V1 neurons through training a self-attention DNN model to reconstruct stimuli from neuronal responses. The SA-DNN model consisted of embedding, positional encoding, self-attention, and unembedding modules, as well as a fully-connected feedforward layer. The model inputs were responses of over one thousand neurons to a specific Gabor, while the model output was the reconstructed Gabor image. The self-attention mechanism can reveal stimulus-specific two-way functional connections among neurons under various stimulus conditions. The results suggest: (1) A small number of key neurons received high attention scores from other neurons and played a dominant role in image reconstruction, while contributions from the remaining neurons and their connections were negligible. (2) These key neurons tended to prefer the stimulus orientation, and received attention from other neurons tuned to all orientations and at various distances within the same FOV. (3) The population orientation tuning functions of key neurons were greatly sharpened when their responses were multiplied by corresponding attention scores, resulting in disproportionally sharpened slopes, as well as reduced bandwidths. (4) Upon removal of identified key neurons, the model could select replacing key neurons that shared similar characteristics of previous ones, so that the ability of effective orientation coding was retained. These findings suggest ideal super sparse orientation coding in V1 by a few key neurons that receive high attention scores from most

neurons. Compared to population orientation tuning without self-attention, the superb orientation tuning supercharged by self-attention resembles the high psychophysical orientation sensitivity in primates.
Acknowledgements: School of Psychological and Cognitive Sciences.

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Exploring new methods to re-construct artwork for vision research

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The Virtual Reality reconstruction of the Carafa Chapel in Rome which we presented at ECVP 2023 did demonstrate the opportunities and challenges to move on from the amazement of being able to show and explore a hidden renaissance jewel in great detail in the lab as a starting point for studying artwork closeup, at any time, and without having limited access. Taking a lead from this initial step, we are developing further methods to document, store, and study perceptual/aesthetic responses in this rich environment. One major progress moving from indoors artwork space to outdoors environments, such as architecture and sculptures (but equally useful for exploring landscapes), is the use of a drone, which circles in well controlled paths in the 3D space, while collecting high-resolution surface maps, using (a) point clouds captured by a Lidar scanner and (b) high-resolution video images taken from a large set of viewpoints on a spiral trajectory around the object of interest. From these data we generate a 3-dimensional model using photogrammetric techniques – which then can be easily incorporated in VR environments to be examined by observers in the VR lab. Using an eye-tracking enhanced VR headset provides experimenters with an opportunity to explore the visual experience of participants. We will present pilot data from a sculpture of Queen Victoria, situated in the north quadrangle of the historic Founders Building at RHUL, to demonstrate the feasibility of using these new methods to understand the aesthetic experience of large 3D monuments that participants have in the virtual world.

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Differential Event-Related and Oscillatory Components of EEG Response to Emotional Body Movement

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Humans are highly sensitive to the emotional content of body movements, but what neural mechanisms underlie this perceptual ability? Previous research using electroencephalography (EEG) has focused on reductions, or suppression, of the mu rhythm (8-13 Hz), an oscillation over sensorimotor cortex, when observing the actions of others. However, many previous studies on the mu rhythm have used highly repetitive and affectively-neutral stimuli (e.g., hand opening/closing), raising the question of whether this oscillation truly captures more dynamic, expressive movements associated with emotion. Here we examined neural responses to emotional vs. neutral whole-body movements using point-light displays (PLDs) in high-density 128-channel EEG (N = 117). Consistent with prior work, we found significant mu suppression for coherent, meaningful biological motion compared to scrambled versions of the same stimuli. However, this reduction was not significantly different for emotional vs. neutral PLDs, suggesting that mu suppression reflects more general processing of human body movements. In contrast, event-related potentials (ERPs) revealed significant sustained activity for emotional vs. neutral PLDs at frontal and central sensors during the same time window. Together, these data support the contribution of neural signals in both the time and frequency domains to perceptual processing of body movements, but that more idiosyncratic and expressive emotional movements may be better characterized in the time domain.
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Attention Distorts Space, Including Cross-Modal Illusions

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In the audiovisual rabbit illusion, three beeps and two flashes presented at different locations create the perception of an extra illusory flash between the two real flashes. The postdiction effect of the later real flash indicates the perceived location of the illusory flash between the two real flashes. Studies suggest that attention influences perceptual variation in estimating the stimulus location and attracts stimuli with higher spatial uncertainty. Our study examines attention's impact on the perceived location of the audiovisual rabbit illusory flash. We displayed four small red circles surrounding the fixation point, with two positioned in the upper visual field and two in the lower visual field, near potential locations of the real flashes. One of the circles would change to yellow 200 ms before the onset of the first real flash (Experiment 1) or after the offset of the last real flash (Experiment 2), serving as an exogenous cue to direct participants' attention. Attention distorted the perceived location of the illusory flash towards the first real flash in Experiment 1 but not in Experiment 2. These results suggest that pre-cue attention can attract the illusory flash to the first real flash, indicating the crucial role of early attentional selection in localizing cross-modal illusions. Conversely, post-cue attention fails to enhance postdiction to attract the illusory flash closer to the last real flash, indicating that the perceptual location of the stimulus is not remapped through late sensory reactivation. Moreover, the illusion rate remained unaffected by attentional manipulation in both experiments, indicating cross-modal binding without attention. These findings shed light on the interplay between attention and multisensory integration, demonstrating how attention can bias the perceived location of illusory stimuli.
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Is visual exploration on smartphones comparable to that on computers?

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Mechanisms involved in visual exploration have predominantly been studied on images displayed on computer screens, neglecting smartphones which are often more used nowadays. For the first time, we investigate the impact of well-known bottom-up and top-down factors from computer studies within an interactive paradigm on smartphones. 21 participants took part in free-viewing and target-searching tasks involving natural images and scrollable web pages on smartphones with varying social and emotional contents. Results were compared to those obtained in an identical study conducted on computer screens by different subjects. Analyses of fixation durations (associated with depth of processing), saccade amplitudes (indicative of spatial attention deployment) and the Coefficient K (marker of visual processing modes) of over 1000 trials revealed that visual exploration patterns on smartphones closely resemble those on computers with an increase in fixation durations and a decrease in saccade amplitudes over time. Consequently, participants initially first exhibited an ambient mode (short fixation durations and long saccade amplitudes), then transitioned to a focal mode (long fixation durations and small saccade amplitudes). Furthermore, results indicated significant similar effects of task, stimulus type and emotional content for both computers and smartphones only on fixation durations. Overall, these findings underscore that, during visual exploration, fixation durations remain reliable indicators between smartphones and computers, while saccade amplitudes and the Coefficient K, differ. Their inconsistency across devices may be due to physical screen size properties while fixation durations better reflect the visual processing mode online. Importantly, our results demonstrate that the patterns and metrics of eye movements remain sensitive to cognitive factors even during visual exploration on smartphones.

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The correspondence of prior audio-visual information influences rule-based category learning

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Categories are often characterised by multisensory features and are driven by sensory and top-down (e.g., prior knowledge) processes. Here, we investigated whether the nature of prior unimodal exposure to a cross-modal category structure influenced subsequent cross-modal category learning. In a mixed-design online study, 16 participants learned to categorise stimuli as ‘safe’ or ‘toxic’. In an initial learning phase, one group of participants (the unimodal correspondence group) learned to categorise the stimuli using a unimodal visual rule (‘safe’ = high spatial frequency, sf; ‘toxic’ = low sf) and, separately, a corresponding unimodal auditory rule (‘safe’ = high pitch, ‘toxic’ = low pitch). Conversely, a second group of participants (the unimodal non-correspondence group) learned one rule for vision (‘safe’ = high sf; ‘toxic’ = low sf) and a contrasting rule for audition (‘safe’ = low pitch, ‘toxic’ = high pitch). Both groups subsequently learned to categorise corresponding and non-corresponding audio-visual exemplars using a cross-modal correspondence rule (e.g., ‘safe’ = corresponding dimensions, ‘toxic’ = non-corresponding dimensions). Therefore, the unimodal rules were either correctly, incorrectly or not at all predictive of cross-modal category membership. Results indicated that stronger learning occurred for exemplars that were the less predictable (i.e., did not follow the unimodally learned category structure) versus highly predictable (i.e., did follow the unimodally learned category structure). Compared to the unimodal non-correspondence group, the unimodal correspondence group showed weaker learning of novel exemplars and were consistently less accurate at re-categorising incorrectly predicted exemplars (versus the correctly predicted exemplars). Therefore, although categories are flexible, a learned category structure defined unimodally by corresponding audio-visual information is less adaptable, possibly reflecting the stronger coupling/persistence of cross-modal correspondences and their associated category representation in memory. Our findings shed light on how prior sensory information influences category adaptation in a multisensory context.
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Predicting “Aha!” moments by facial expressions

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When a person solves problems, s/he experiences occasionally “Aha!” when finding a creative thought or insight. We examined whether the Aha! experience could be predicted from facial expressions automatically with a machine learning technique. We conducted experiments of Japanese Remote Associates Test and Matchstick Arithmetic problem, both of which often require insight to solve. Participants tried to solve problems on a display while their face image was recorded by a web-camera (60Hz). To identify factors related to Aha! moments, we constructed a classifier of Aha! and not Aha! trials by training with facial expressions and subjective reports of Aha! experience. The classifier predicted Aha! trials with an accuracy higher than chance with face features recorded two to one second before response. SHAP analysis, which outputs an index on how largely each feature contributes to the prediction, showed that Lip Stretcher, Lip Corner Puller and Lip Tightener are the top three important factors. They suggest that the bottom half of face is more closely related to the mental state of Aha! than the top half. We, then, tried the same prediction but with face feature at the beginning of trial, at which time face should not be related to Aha! moment. To our surprise, face features from very first period of trial succeeded to predict Aha! trial while important features are not the same (Outer Brow Raiser, Nose Wrinkler, Lip Corner Puller). We examined whether the classifier trained by early/late data can be used to predict Aha! trials with late/early data. The cross validation showed no significant prediction, which suggests that there are two processes related to the mental state of Aha! One is directly related to the moment of Aha! and the other may be the mental state suited for creative thinking.

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Measuring time-dependent evidence accumulation based on confidence reports

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Drift diffusion models (DDMs) are the key method to investigate the time course of perceptual evidence accumulation. While DDMs aim to track the time course of internal evidence accumulation, we here present an approach to study the time course of accumulation from external stimulation: We study how much evidence observers can draw from individual time intervals during stimulus presentation. Our method exploits a striking similarity in the mathematical formulations between DDMs and confidence weighted majority voting (which is typically used to study group decisions): Each time step in a DDM accumulates evidence in the same way as a group of experts accumulates evidence when an additional expert joins the group. Using participants' confidence reports we quantify the evidence distribution at different time points (similar to a sequential probability ratio tests). In two experiments (N=17 participants, each measured for 6 hours), we demonstrate (a) an increasing evidence accumulation rate in a discrimination task with visual gratings, and (b) a constant accumulation rate with moving dot stimuli. These results provide a direct assessment of the time course of evidence accumulation with the main advantage of reducing model assumptions: The core assumption of traditional DDMs is the independence of evidence accumulation in single time steps. This assumption is unrealistic because the speed at which the visual system can extract evidence at any time step depends on how much evidence it has already extracted. Our approach can deal with these dependencies by exploiting simple mathematical principles. The drawback of our approach is its reliance on (possibly biased) confidence reports which we attempt to resolve by using a log-odds based calibration. Overall, our approach provides a complementary method to measure changes in the time course of evidence accumulation in visual processing.
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Surviving continuous flash suppression: A two-photon calcium imaging study in macaque V1

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Continuous flash suppression (CFS) has been widely used to study visual consciousness or awareness. Although the flashing Mondrian noise presented to one eye can suppress the perception of a high-contrast stimulus presented to the other eye, some low-level visual information can survive the suppression and participate in downstream visual processing subconsciously. However, it remains elusive how the responses of V1 neurons, most of which receive binocular inputs, are affected by CFS. To address this issue, we utilized two-photon calcium imaging to record responses of thousands of superficial-layer V1 neurons to a target under CFS in two awake, fixating macaques. The target was a circular-windowed square-wave grating (d=1°, SF=3/6 cpd, contrast=0.45, drifting speed=4°/s). The flashing stimulus was a circular Mondrian noise pattern (d=1.89°, contrast=0.50, TF=10 Hz). The stimuli were presented for 1000-ms with 1500-ms intervals. The square-wave grating at various orientations was first presented alone to either eye to identify oriented-tuned V1 neurons (~900 per FOV) and calculate each neuron's ocular dominance index (ODI). Then the grating target was presented to one eye and the flashing noise to the other eye to measure neuronal responses under CFS. With the presence of flashing noise, orientation responses of neurons preferring the noise eye (ODI>0.2), in the form of population orientation tuning function, were completely suppressed (by 96.3%) without measurable bandwidth, and those preferring both eyes (0.2>ODI>-0.2) were also severely suppressed (by 83.6%) with unmeasurable or very wide bandwidth. However, although the responses of neurons preferred the grating eye were also significantly suppressed (by 47.2%), the tuning bandwidth was still measurable, which increased from 11-13° to 19-21° (half-height half-width). These results indicate that only orientation responses in V1 neurons preferring the target eye can partially survive continuous flash suppression, while orientation responses of other neurons are mostly wiped out.
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Comparing method of adjustment and continuous psychophysics for assessing the perceptual size-distance relationship

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In recent years, continuous psychophysics (Bonnen et al., JOV 2015) has gained popularity for swiftly and engagingly measuring visual sensitivity. In this experiment, we assessed people's ability to correctly estimate an object's size or position based on how far they appear in a 2D scene. We compared a traditional method of adjustment – modified from a 'distance perception in a 2D scene' experiment (Kim et al., Perception 2022) with a continuous psychophysics method. Participants adjusted the size and position of a target (an image of a cereal box) in a full-size 2D hallway scene projected onto a wall with a ground plane continuous with the experimental room, either adjusting its position based on its size (Size-to-Position task) or resizing it based on its position in the hallway (Position-to-Size task) to make it appear to be the correct size as the box they held in their hands. In the traditional method, targets were displayed with the size or position equivalent to distances of 4m, 8m, 12m, or 16m. For each trial, participants adjusted the target to be the correct position or size. In the continuous psychophysics method, targets started at three possible sizes (size-to-position) or positions (position-to-size), equivalent to distances 2.5±1.25m, 4±1.25m, or 8±1.25m (randomly picked within the range using a normal distribution), which changed randomly every 500ms for 90 seconds in a "random walk". Participants had to continuously adjust the target by means of a mouse to keep it at the perceived correct position/size combination. The relationship between target size and position indicated participants were able to accurately adjust the target's position and size. No significant difference between the two methods was found. This result further verifies that the data obtained using continuous psychophysics is compatible with those from traditional psychophysics.
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Separating out distractor suppression from attentional guidance using predictability of feature and location

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Suppression of distractors is considered crucial for efficient attentional selection. Distractor suppression is seen as reduction in magnitude of attention captured by an additional feature singleton that is relatively consistently presented in a location. However, this reduction in capture is not observed when feature of distractor is consistent. We argue that the relative importance of feature and location is not the same in task employed to test distractor suppression, especially if the target feature can be used for attentional guidance. It is unclear to what extent the data reflects reduced attention capture or increased distractor suppression. In the present study, we separate the search task from target and distractor singletons and test how predictability associated with feature and location contributes to distractor suppression. We performed three experiments by modifying the additional singleton paradigm. In the first experiment, both the singletons could contain the target but with different probabilities (70% or 30%). In the second experiment, we picked two locations, one with higher probability of containing the target than the other. We compare the findings with a control condition with no location or feature-based bias in the search display. Thus, we could separately investigate the effect of a distractor feature and location on attentional guidance. We observed relatively flat search slopes for both the high and low probability feature (Exp1) and location (Exp2), but a steep search slope in the control experiment (Exp3), indicating easy and efficient search when the target/distractor was either a predictable feature or location. Moreover, the difference in reaction time between the high and low probability conditions for feature and location (Exp1&2) were comparable and faster than the control, indicating that predictability of both feature and location had improved search. Hence, the study shows that typical measures of distractor suppression are conflated by effects of attention capture.

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Why does touch interfere differentially with multiple-object tracking performance?

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Many everyday tasks require keeping track of the positions of several moving items among others (e.g. crossing the street, driving). This ability to keep track of the positions of a subset of items (targets) among identical others (distractors), is referred to as multiple-object tracking (MOT) and is thought to employ cognitive mechanisms that are also required for coordinated actions. In the present study, we sought out to investigate this theory using a modified version of the MOT task where participants performed two tasks simultaneously: 1) track targets moving among identical distractors (standard MOT task) and 2) touch any item in MOT (target or distractor) that changes colour. Baseline conditions were also included to assess single task performance for both tasks. Results demonstrated that touching distractors in MOT interfered appreciably more with tracking performance than touching targets (lower tracking accuracy) and resulted in slower touch response times. Interestingly, button presses to colour changing items in MOT did not significantly interfere with MOT performance, providing further evidence that this detriment is specific to touch. Taken together, findings support the contention of a shared cognitive mechanism employed in tracking and visually guided actions. Here we also discuss and provide evidence for possible specific mechanisms that may be responsible for the observed interference.

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Blink-initiated behavioral oscillation of detection performance at alpha rhythms

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Rhythms in the brain modulate our perception (e.g., VanRullen, 2016). The link between neural oscillations and behavior has been established in many domains, from neurophysiology to human neuroimaging such as EEG/MEG. Also in behavioral studies, it has been widely demonstrated that a visual transient modulates the accuracy and/or sensitivity for the subsequent stimuli periodically, which has been interpreted as the transient signal "resetting" the ongoing oscillatory activities. In addition to the external cues, behavioral oscillations can be observed time-locked to our own actions such as saccade (Benedetto & Morrone, 2017) and arm movement (Tomassini et al., 2015). Here I show that eye blinks also periodically modulate perceptual accuracy. In the experiment, a near-threshold Gabor patch was briefly presented in dynamic random noise on either side of the fixation point. Participants were asked to report which location the Gabor appeared as quickly as possible. Each noise sequence lasted approximately one minute, and within which the target Gabor appeared about 20 times at random intervals of 2-4 seconds. Participants blinked naturally at their pace, and the detection accuracy was calculated separately for various blink-to-target intervals. Using Fourier analysis and permutation tests, I confirmed that the time course of detection accuracy oscillated at alpha rhythms, suggesting that the alpha oscillations induced (or reset) by eye blinks are involved in sampling external perceptual information. We will further discuss whether/how this blink-initiated behavioral oscillation is associated with the reactivation of the dorsal attention network after eye blinks (e.g., Nakano et al., 2013).

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Gravity as a cue to distance or speed in motion perception

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Because gravity is a constant on Earth, we should, in principle, be able to infer the size and distance of falling objects based on their angular speed and acceleration. A large, distant falling object projects a slower visual motion than a small, nearby object of the same retinal size. This was exploited in early movie special effects by filming small model scenes (e.g., a train falling off a mountain track) in

slow motion to give the impression of a full-sized scene. However, if other cues or assumptions about absolute distance and size intervene (e.g., due to view angle or a prior on the likely size and/or distance of objects), observers might also perceive the motion as unfolding slower or faster than would occur in real life. Here, we investigated how changes in the overall scale of a scene influence the perception of size, distance, time, and speed. Participants were shown a series of rendered movies depicting a ball rolling off a cliff edge of different physical heights. In a control condition, the stimuli were also shown upside-down. The simulated scene was linearly scaled across multiple orders of magnitude such that the cliff and ball had a constant visual angle across all conditions. Participants assessed both the speed of the ball and the altitude of the cliff. In a second task with the same stimuli, they also adjusted the speed of the movie playback to match what they would typically observe in everyday life. We found systematic variations in motion and time perception depending on the height of the cliff, suggesting that participants cannot perfectly infer size and distance from gravity.

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Visually-guided natural human grasping with articulated hands

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Humans have an unparalleled ability to grasp and manipulate objects. This is made possible by the exquisite interplay between the visual system—which enables the selection of appropriate contact regions on object surfaces—and the rich articulation and soft tissues of the human hand, which conforms to the grasped object. Yet, most studies on human grasping behavior have investigated grasping under highly constrained conditions, mainly focusing on precision grip grasps and approximating hand-object contact as points rather than full contact regions. Here, we sought to characterize human grasping behavior under more natural conditions. First, we combined techniques from motion tracking, computer graphics and deep learning to reconstruct full hand meshes and poses, and developed a method to use these reconstructions to estimate contact regions between the hand and objects. We then collected a comprehensive dataset of human grasping behavior featuring a wide variety of tasks and objects across multiple sessions. 60 participants first pantomimed hand poses from a standard taxonomy of 33 grasp types. Then, four groups of participants (N=15) each grasped a subset of 7 objects in an unconstrained, precision grip or multi-digit condition for a total of 28 objects across participants. In a third session, we investigated the impact of task by asking participants to grasp objects to lift, use, hand over, turn horizontally, turn vertically or heft them. Our results demonstrate that participants rarely used precision grip grasps, were highly consistent in their selection of contact regions (both within and between participants) and that grasps varied systematically across tasks. Additionally, hand poses did not span the full manifold of pantomimed grasps and could be well explained by a reduced subspace of typical grasps. These findings suggest that typical grasping behavior is highly stereotyped, but not in the ways imposed by previous research.

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Causality perception and sensory predictions are subject to different sources of uncertainty

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How do observers assign causes and effects to sources in their environment, particularly when only visual information is available? The perception of causality is believed to be influenced by a combination of the physical plausibility of a visual scene and an observer's subjective perception that one event is regularly preceded by another. In this study, we employed Michotte's classic launching paradigms – namely, 2D animations mimicking a two-object collision – and collected the same participants' sensory uncertainty around moving trajectories and causal impressions. We displayed a launching paradigm up to the point of collision and instructed participants to indicate the predicted outgoing trajectory of the second object in an adjustment task. In a second experiment, observers judged causality in launching animations after viewing a full launching display. The launching animations in the latter task either showed physically plausible moving trajectories or systematic offsets from physically plausible angles that were added to the second object's moving trajectory. In both experiments, objects collided at uniformly-sampled angles between 0° and 360°. The trajectory prediction data clustered toward the physically true moving trajectory, indicating that participants' reports are qualitatively aligned with Newtonian mechanics. The error around the predictions furthermore increased for oblique orientations of the collision, marking an oblique effect. Causal impressions broadly decreased for large angle offsets and showed no other tendencies that align directly with the prediction data. This suggests that there are more sensory and cognitive sources informing causal impressions than the prediction of moving trajectory and its associated uncertainty. We speculate that responses in both tasks are subject to a memory component, where new evidence overwrites previous evidence (i.e. postdiction). Observers might hold a strong prior belief that most rigid-body interactions will be causal, and therefore require strong evidence of violation to report "non-causal".

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Test-Retest Reliability for Multiple-Target Visual Search: Eye-Tracking and Performance Metrics

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Visual search plays a critical role in life-saving careers such as radiology and airport security. There has been growing interest in exploring factors specific to individual observers (e.g., personality, strategy) that can affect search accuracy; however, paradigms and measures with low test-retest reliability are inappropriate for the exploration of individual differences. There is value in investigating individual differences in multiple-target search due to its relevance for professional searches, but the test-retest reliability of multiple-target search and its associated eye movements remains unknown. We tested a sample of undergraduate participants (n = 75) in two sessions

(separated by 1-3 weeks) on a multiple-target search task (0, 1, or 2 target 'T' shapes, presented at high or low salience, amongst distractor 'L' shapes). We measured accuracy, response time, and eye movements and assessed performance across single-, dual-, and no-target trials. The results revealed a range of test-retest reliabilities: Intraclass correlation coefficients (ICC) for accuracy measures ranged from fair (.25 ≤ ICC < .4) to moderate (.4 ≤ ICC < .6), and more difficult-to-spot "low-salience" targets produced higher reliabilities than more easy-to-spot "high-salience" targets. Response time measures were overall more reliable than accuracy measures, ranging from moderate (.4 ≤ ICC < .6) to good (.6 ≤ ICC < .8). Eye-tracking measures (e.g., number of fixations, fixation duration, initiation time, saccade rate, saccade amplitude) had the best levels of reliability overall, ranging from good (.6 ≤ ICC < .8) to excellent (ICC ≥ .8), except for saccade duration which was moderate. These results indicate that only some multiple-target search metrics offer a strong basis for assessing individual differences and that future work should consider a multi-faceted approach to investigating visual search behaviour, integrating performance and eye-tracking measures.
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Perceived height of trees standing on flat or sloped ground: a variation of horizontal-vertical illusion

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We tend to perceive a vertical line to be larger than the horizontal line of the same length. This tendency, called the horizontal-vertical illusion (HVI), is true indoors (Künnapas, 1955; Prinzmetal & Gettleman, 1993) and outdoors (Higashiyama, 1996; Howe, 2005). From this well-known finding, we can predict that a tree standing on the ground appears larger than the same-sized tree lying on the ground. Contrary to this finding, however, there is an unconfirmed idea told among lumberjacks: Some accidents they had while cutting down trees may be due to perceiving the trees shorter, so that they would not be able to refuge from the falling tree. This idea was tested in cedar forest with flat and sloped ground. For this aim, we used a tree on flat ground, a tree on the top of slope, and a tree at the bottom of slope, and three heights upward from the bottom of each tree were designated as vertical standards. Additionally, three lateral separations among other trees standing on flat ground were designated for horizontal standards. By each of five participants approaching or receding from each standard, the distance from the participant to the tree was matched to each standard. The mean matched distance was plotted against the standard and then the ratios of the matched vertical distance to the matched horizontal distance were estimated for each tree as the index of HVI. It was found that as the standard increased from 5 m to 40 m, the amount of HVI decreased from 1.5 to 1.1. The amount of HVI depended on the place on which the tree was standing: The large HVI was found for the tree on flat ground and the small HVI was found for the trees on the top of slope and at the bottom of slope.

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The Long-Term Influence of Red, Blue, and Green on Eye-Hand Coordination training

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Eye-hand coordination is a fundamental skill in daily activities and professional domains including surgery, dentistry, fine arts, athletic training, engineering, and piloting. The mirror drawing is a widely used task that assesses and improves fine motor control, coordination, and the ability to perceive spatial information. However, limited research exists on the impact of repetitive training on mirror drawing in enhancing eye-hand coordination, particularly when employing color stimuli. The primary objective of this study is to investigate the efficacy of the mirror drawing task in improving eye-hand coordination skills with different colors in a longitudinal study. Twelve participants were invited to conduct a mirror drawing experiment. In a pre-experimental session, each participant was asked to trace inside the lines of a white star positioned against background sheets of distinct RGB colors, specifically blue (RGB: 0, 0, 255), red (RGB: 255, 0, 0), and green (RGB: 0, 255, 0), and using a mirror to assess hand-eye coordination. Subsequently, participants engaged in three consecutive days of training, performing 10 trials for each color. During the training, the time taken to complete each trial and the number of errors, defined as instances where the pen touched or deviated from the star's borderlines, were recorded. A counterbalancing system was employed to assign colors to participants. Following the training period, participants underwent a post-experimental session, repeating the task once for each color. Our findings suggest that even though there is a deviation between different colors in the pre-training session, this effect dampens during the training session and in the post-training session in terms of time and error rate. These findings highlight that the color cues have an impact on the motor performance of the novices, but this discrepancy disappears after the eye-hand coordination training.

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Experience-dependent biases in face discrimination reveal associations between perceptual specialization and narrowing

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Background. Experience modulates face processing abilities so that face recognition improves with development, especially for more frequently experienced faces (e.g., own-race faces). Although advanced models describe how experience generally modulates perception, the mechanism by which exposure refines internal perceptual representations of faces is unknown. To address this issue, we investigated face processing both in typical development and in autism. Method. Participants performed same-different judgments in a serial discrimination task where two consecutive faces were drawn from a distribution of morphed faces. Utilization of stimulus statistics was measured by testing the gravitation of face representations towards the mean of a range of morphed faces around which they were sampled. Results. The results demonstrated regression of face representations towards the experienced mean; however, the dynamics of the perceptual bias, probed by trial-by-trial performance, indicated different timescales of the bias, depending on perceptual expertise, age, and proficiency level in face recognition: in adults, the "typical" internal representation of the averaged face formed for

own-race faces was constantly updated by recently encountered faces. For other-race faces, an internal representation was formed based on the overall average of the exposed faces, but only for those with low proficiency in face recognition. Interestingly, at age 9-10, perceptual biases were similar for own- and other-race faces, with overall and recent exposure similarly biasing performance. In autism, performance was substantially weaker and mostly biased by recent exposure, with weak representation of the average face for both face races. Conclusions. The findings suggest a mechanism by which short- and long-term of exposure refines face representations. They also reveal that deficits in face recognition in autism do not reflect delayed development, nor an overall weaker perceptual system. More broadly, the results suggest strong associations between levels of specialization and the extent to which perceptual representations become narrowly tuned.

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Investigating the effect of hemispheric dominance on perceptual bias in 3D shape-from-shading: Evidence from left-handers

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3D shape from shading relies on the implicit assumption of a light source positioned left of zenith (left bias). It is unknown why this left bias is prevalent, however there is evidence suggesting that left-handers exhibit a reduced left bias compared to right-handers. This difference may be attributed to learned experiences, as left-handers would normally prefer a right light source when writing, to avoid shadow cast. Another possibility, which is explored in this study, is that the reduced left bias reflects variability in hemispheric lateralisation among left handers: while some left-handers are left hemisphere dominant (typical), like most right-handers, others are right hemisphere dominant (opposite). We hypothesise that left-handers with typical hemisphere dominance will exhibit a left bias, whereas left-handers with the opposite hemisphere dominance will exhibit a right bias. Left-handers whose hemispheric dominance has been measured in an fMRI study are recruited. All participants complete a 3D shape judgement task where they determine whether a stimulus is concave or convex when presented in different orientations. The bias of each participant is computed by the proportion of convex responses in relation to each lighting direction. This study could contribute to our understanding of the origins of the left bias in 3D shape from shading.

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Categorizing Deterministic Errors and Stochastic Errors in Visual Search

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Human observers make errors in almost any visual search task. One way those errors can be categorized is as “deterministic” or “stochastic”. An error is completely “deterministic” if that error will be made every time that a specific observer searches through a specific stimulus. Alternatively, a stochastic error occurs randomly with some probability from trial to trial. A lot of effort has been invested in finding ways to reduce errors, but different types of errors might need to be targeted differently. In this study, we aimed to empirically categorize miss errors in a simple T-vs-L search task by presenting each search display twice. If the observer misses a display the first time, what is the chance that they will miss it the second time? In addition, we tested interventions to reduce these errors. In Experiment 1, we presented white letters on a uniform grey background. These clearly visible letters led to almost completely stochastic miss errors. In Experiments 2a and 2b, we manipulated the visibility of letters by varying their grey levels and presenting them on a noisy background. This manipulation resulted in a mix of stochastic and deterministic errors, with lower-contrast, but still visible, targets producing more deterministic errors. In Experiment 3, using the same stimuli as in Experiment 2b, we tested several cueing interventions to reduce miss errors. Interventions that guided attention around the display without knowing anything about the content of that display failed to have any effect (Experiments 3a and 3b), but cueing all item locations did succeed in reducing deterministic errors (Experiment 3c). Eye tracking data showed that it was specifically the low-contrast targets that profited from having their location cued. These results point to strategies of error mitigation that may be worth trying in socially important, real-life tasks.

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Optic flow parsing in Persistent Postural Perceptual Dizziness (PPPD) – a pilot study

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PPPD patients often perceive instability of themselves and/or their surroundings. Here, we report the findings of a pilot study examining whether PPPD symptoms might, in part, relate to altered optic flow parsing – a purely visual mechanism thought to help us compensate for the visual consequences of self-movement. Five PPPD patients and 30 undergraduate participants were presented with a left/right hemifield of expanding/contracting optic flow with their head stabilised on a chin rest. In the opposite hemifield, a probe object moved left or right with speed controlled adaptively from trial to trial with a Kesten staircase. Participants reported whether the probe appeared to move left or right (2AFC). Under the flow parsing account, the hemifield of flow triggers a global subtraction process resulting in a bias in perceived probe movement. We fitted a psychometric function to the 2AFC data relating probe velocity to the probability of a rightwards response, and recorded the probe velocity at which participants were equally likely to report leftwards and rightwards probe movement. This marks the bias in perceived probe movement due to flow parsing. The qualitative pattern of biases obtained over different conditions (right/left hemifield x expanding/contracting flow) for patients was similar to the control group, however the magnitude of the bias was reduced by a factor of two in the PPPD group. These preliminary data suggest that flow parsing is considerably weaker in people with PPPD. Weaker flow parsing would result in inappropriate compensation for optic flow signals accompanying self-movement, leading to inappropriate perception of scene-relative movement, a hallmark of PPPD. Our previous work provided evidence that flow parsing is boosted in older participants, so our findings are unlikely to be due to the age difference between our PPPD and control groups. This work precedes our STARDUST project, which aims to replicate this finding.

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Accuracy and precision of Apple's Truedepth camera and ARKit for affordable head and eye tracking

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Eye tracking is usually accomplished with expensive, specialized systems; either wearable, head-mounted devices, or stationary desktop solutions. The same is true for the assessment of head and body pose. Until recently, these required motion capture systems with multiple cameras and attaching an array of trackable markers to the tracked person's body. In current settings, both sensory technology and computer vision solutions have matured to a point where both gaze tracking and body tracking can be accomplished with solutions that are lightweight, less intrusive, and affordable. Here, we are reporting on the feasibility of employing Apple's Truedepth sensor along with iOS' ARKit API to accomplish tracking of head pose, facial motion, and eye gaze. We first present data accuracy and precision of reported head position, head orientation, and gaze direction, alongside metrics regarding real-time capabilities of ARKit. Participants were seated in front of an iPad that displayed an array of targets upon which participants were instructed to fixate. ARKit's reported head pose and eye gaze is logged and internal consistency of the ARKit system was evaluated against ground truth metrics. This is achieved by collecting head pose data with a high-end optical motion capture system and gaze data with a high-resolution eye tracker. Together, these allow us to decompose inconsistencies in the ARKit data into isolated errors of head location, head orientation, eye location, and gaze direction in head-fixed coordinates. The data revealed systematic offsets which can be accounted for by targeted calibration procedures. Limitations in precision were primarily due to gaze measurements and only to a much smaller part to head pose. Realtime capabilities are impressive. We measure latencies small enough to use ARKit head tracking to simulate self-induced motion parallax and present a demonstration of how this can be used to implement viewpoint-contingent depth displays.

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Feedback-based training improves the accuracy of stimulus memorability judgments

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Individuals tend to remember and forget the same faces, scenes, objects, and more, a result of the intrinsic memorability of the items. Despite this consistency in memory performance, previous findings suggest that people may not be fully accurate nor consistent when subjectively judging the memorability of images. Across four experiments (one containing face images, one containing scene images, a replication, and a control experiment), we aimed to test whether participants receiving feedback-based training could learn image memorability. Participants on the online platform Prolific (N = 400) viewed a randomized sequence of 180 images found to be either highly memorable or highly forgettable in previous studies. On each trial, participants judged whether the image was memorable or forgettable, and were then told its correct category. Afterwards, they reported the strategies they had used to perform the task. We found that participants slightly improved in their judgments of scene images over the course of both experiments, but did not improve in response to face images. Those who reported using characteristic features of the scenes to judge their memorability showed greater learning. However, participants never reached the performance level of ResMem, the leading deep neural network for estimating image memorability. These results suggest that with training, people can develop a more accurate understanding of stimulus memorability, but are unable to access its full variance.
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Pseudo-cost of acting biases perceptual decision making.

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While it is commonly known that a character of a stimulus influences decision-making that results in motor responses, conversely, motor responses affect perceptual decision-making. Particularly, the cost of acting to report one's decision influences perceptual decision-making, and decisions are biased toward avoiding this cost. However, it is unclear whether this cost needs to be elicited through actual motor actions. In this study, we investigated whether pseudo-costs of acting, which do not require actual motor actions, affected perceptual decision-making. Recently, technology has been developed wherein subjective costs of acting can be manipulated by pseudo-motor costs represented through visual stimuli in VR, without altering the physical costs of acting. In our current study, we utilized this technology to evaluate the impact of pseudo-costs of acting on perceptual decision-making. Seventeen participants watched the visual motion in VR. They were required to report the direction of the visual motion by left or right rotating their head by 45 degrees. In the large visual rotation condition, when physically rotating the head was by 45 degrees, the rotation depicted in VR was 55 degrees, whereas in the small rotation condition, it was 45 degrees. The larger or small rotation condition was assigned either left or right direction. To assess the contribution of the visual rotation condition, a linear mixed model was used to test whether left of right that was assigned to the large rotation condition predicted the "right" response. As a result, the "right" response tended to occur more frequently when the left side was assigned as the large rotation condition compared to when the right side was assigned ($t(16)=-2.28$, $p=.0374$, $R2=0.327$, adjusted $R2=0.326$). This study clearly showed that pseudo-cost of acting, which is not incurred through actual motor actions, biases perceptual decision making.

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The oblique effect in motion detection and identification - a neural and behavioural investigation

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Motion processing is an essential perceptual ability that helps us navigate and interact with our environment. Interestingly, previous studies have shown that we do not perceive all motion directions equally: cardinal motion directions such as horizontal and vertical motion, are perceived better than oblique ones. Here, we used electroencephalography (EEG) to investigate the neurophysiological mechanisms underlying the oblique effect. In two experiments, we investigated motion detection and identification with random dot kinematograms while continuous EEG was recorded. In line with previous research, we found support for the oblique effect with better performance for cardinal motion directions in the identification task. There was no behavioural difference between motion directions in the detection task. Event-related potential analysis revealed strong motion-induced responses at occipitotemporal electrodes in both experiments, but these did not differ in amplitude across motion directions. Representational Similarity Analysis revealed that metric models, where the similarity between neural representations is expected to be determined by the difference in motion directions, explained neural representations better than categorical models, where the similarity between representations is expected to vary only across categorical boundaries. This result suggests that motion direction representations are fine-grained and that their (dis)similarity is sensitive to the absolute differences in directions. The models were also better at capturing neural representations in the identification than in the detection task, primarily at late time-points, starting about 250 ms after stimulus onset. These findings suggest that the task, identification, or detection, substantially affects neural representations of motion direction and that instantiating these neural representations require considerable processing time.

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Interaction of hand posture and kinematics dimensions during retrieval of action tool knowledge

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Our ability to use tools is heavily based on semantic tool knowledge and action tool knowledge, enabling us to specify the actions required to using tools. Action tool knowledge encompasses various dimensions, notably hand posture (i.e., the shape of the hand to grasp a tool for its subsequent use) and kinematics (i.e., the way the tool is moved to perform a given action). Neuropsychological data report dissociations between these two dimensions suggesting that they rely, at least in part, on distinct cognitive mechanisms. However, in psychological studies, the interaction between these two dimensions is rarely investigated. To address this question, we conducted two experiments to investigate the relationship between these two dimensions. In a first experiment, 48 healthy participants were asked to judge whether pairs of objects shared the same hand posture, same kinematics or same function in separate blocks. We found that hand posture and kinematics pairs were processed more slowly than those based on function, confirming that action tool representations are accessed after semantic tool representations. In a second experiment, 48 participants were asked to judge pairs of familiar objects either on the hand posture or on the kinematics dimension. The object pairs could be related or unrelated in terms of hand posture and related or unrelated in terms of kinematics. We observed asymmetric interference effects, with the kinematics dimension being impacted by the hand posture dimension whereas hand posture was more influenced by the visual similarity between objects than the kinematics dimension. These results confirm that kinematics and hand posture are cognitive motor components that mutually interact, with the exception that the hand posture dimension can be more influenced by perceptual components of objects than kinematics dimension.
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Probing Material Perception and Categorization using AI-Generated Images

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Perceptual material categories are defined and distinguished by their characteristic visual appearances. For example, polished wood is recognized from a particular configuration of color, texture, and gloss. To investigate human material categorization and how it relates to particular visual characteristics, we used the AI-based image synthesis tool Midjourney to create photorealistic images of novel hybrid materials, whose appearance lies between familiar categories. We first created "parent images" for 26 material categories, like snow, wood, metal, or plastic. By refining the text prompts, we ensured that each image clearly depicted a single material category without extraneous features of objects or scenes. We then used Midjourney's /blend function to generate novel hybrid materials by blending pairs of images. In Experiment 1 (N=34), observers used a slider labeled with the two parent categories (for example, snow versus wood), to report the perceived category of each hybrid. An optional button let participants indicate if the image looked like neither material. The distribution of slider responses and button presses allowed us to identify the degree and kind of ambiguity of each image; for example, bimodal versus unimodal response distribution. Experiment 2 (N=26) gathered ratings of these images for six dimensions: artificiality, hardness, opacity, roughness, warmth, and wetness. PCA on the ratings revealed that images roughly cluster by the degree and kind of ambiguity. Experiment 3 (N=19) assessed the top and bottom ranked images for each dimension and their hybrid mixtures. Results showed that blending images with contrasting properties (for example, perceived hardness of water versus rock) can evoke intermediate perceptual ratings. Our findings suggest that while the properties of ambiguous hybrid images can sometimes be predicted from their parent images, in other cases, they exhibit completely new appearance characteristics, indicating a structured cognitive space of material categories that do not always blend predictably.
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Duration and luminance intensity of chromatic environments interact to alter our perception of colour.

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Altering a chromatic environment over a period of hours, days, or months, causes enduring changes to the perception of colour. For example, seasonal changes in the colour environment or the natural yellowing of the crystalline lens can influence perception of unique hues. However, little is known about the factors driving chromatic adaptation at a timescale beyond a few minutes. In a series of studies, participants were adapted to red- and blue-filtered goggles. The effects of altering the duration and the luminance of a colour-filtered environment on the appearance of unique hues were measured after five minutes of recovery from the adapting environment. Results suggested that shifts in unique hue appearance increased between 15 minutes and 1 hour of adaptation, but were maintained between 1 and 4 hours. This pattern suggests that this form of adaptation is distinct from short-term (photoreceptor) adaptation, as significant shifts in unique hue perception persisted after five minutes of recovery, and continued to increase after the point at which photoreceptor adaptation should be saturated. The luminance of the adapting environment had a linear impact on the size of the shift in unique hue, with smaller shifts occurring after adaptation to darker environments, implying a 'dose-dependent' effect of the adapting environment on chromatic adaptation. Moreover, full recovery from adaptation occurred within one hour, even in the absence of further light adaptation, suggesting a 'passive' recovery process. These two factors of duration and luminance can be used to model adaptation by predicting the sizes of changes in the L/M cone ratio to the spectra of the altered chromatic environments. This can be used to predict changes in unique hues for a given duration and luminance of an adapting environment with known spectral properties.

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Forward and backward alpha-band travelling waves reflect temporal expectations in a statistical learning paradigm

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According to the Predictive Coding framework, the brain extracts statistical regularities in our environment to generate predictions about incoming sensory stimulation, continuously updating an internal model of the world. Though the possible neural basis of this mechanism is still unclear, alpha-band (8-12Hz) Traveling Waves, known to shape neural excitability while propagating across the cortex, represent an ideal candidate to serve Predictive Coding's flow of information. Within this framework, backward Travelling Waves, i.e., propagating from frontal to occipital regions, encode for predictions of incoming sensory stimuli, whereas forward Traveling Waves, i.e., spreading from occipital to frontal areas, reflect the bottom-up flow of information encoding for prediction errors. One hypothesis that stems from this framework suggests that more reliable predictions prompt stronger backward Travelling Waves, and more unpredictable events produce stronger forward Travelling Waves. Here, we test this hypothesis using a visual statistical learning paradigm, which consists of a stream of geometrical shapes, presented to the subjects at 1 Hz while recording their brain activity via electroencephalography (EEG). Importantly, we manipulated the predictability of the shape stream in five different conditions, from very predictable to completely unpredictable. Despite our behavioral results reveal that participants learned the statistical regularities, our preliminary EEG results show no apparent effect of the predictability in both backward and forward waves. However, we found a very robust and consistent temporal entrainment of these waves at the stimulus presentation rate (i.e., 1Hz), with backward and forward waves in antiphase with each other. Altogether, our findings suggest that, contrarily to what we hypothesized, backward waves do not encode for statistical feature predictions but reflect temporal expectations about new stimulus onset. These results shed new light on the role of travelling waves within the predictive coding framework and open new venues for investigating their functional role.

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Action video games improve phonemic awareness in pre-reader children at risk for developmental dyslexia

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Action video-games (AVGs) could improve reading efficiency, enhancing not only visual attention but also phonological processing. Here we tested the AVG effects upon three consolidated language-based predictors of reading development in a sample of 79 pre-readers at-risk and 41 non-at-risk for developmental dyslexia. At-risk children were impaired in either phonemic awareness (i.e., phoneme discrimination task), phonological working memory (i.e., pseudo-word repetition task) or rapid automatized naming (i.e., RAN of colors task). At-risk children were assigned to different groups by using an unequal allocation randomization: (1) AVG (n = 43), (2) Serious Non-Action Video Game (n = 11), (3) treatment-as-usual (i.e., speech therapy, n = 11), and (4) waiting list (n = 14). Pre- and post-training comparisons show that only phonemic awareness has a significantly higher improvement in the AVG group compared to the waiting list, the non-AVG, and the treatment-as-usual groups, as well as the combined active groups (n = 22). This cross-modal plastic change: (i) leads to a recovery in phonemic awareness when compared to the not-at-risk pre-readers; (ii) is present in more than 80% of AVG at-risk pre-readers, and; (iii) is maintained at a 6-months follow-up. The present findings indicate that this specific multisensory attentional training positively affects how phonemic awareness develops in pre-readers at risk for developmental dyslexia, paving the way for innovative prevention programs.
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Gaze Following in Complex Virtual Environments: Comparing Human and Robot Avatars

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The influence of gaze behaviour on social perception and cognition is pivotal in understanding interactions not only among humans but also between humans and embodied digital technologies such as robots. In our study, we investigate how the gaze of an avatar – either human or robot – influences the gaze of participants, even if it contains no task-relevant information. We constructed a high-fidelity virtual reality resembling corridors in a university office building, and placed automatically generated scientific posters on both side walls. The avatar moved at a moderate walking speed and occasionally glanced at posters. Participants were instructed to follow the avatar through a series of corridors. While participants could control their forward movement speed and had the freedom to move laterally and to look around, they received no specific instructions regarding gaze or posters. We found that in corridors in which the avatar glanced at posters only or mostly on one side, this lateral bias in gaze direction was also present in the participants. In this measure, no difference was observed between human and robot avatars. However, participants' total dwell time on posters was higher when they followed a human avatar compared to a robot. These results show that participants exhibit substantial gaze-following behaviour, even if the gaze of the other individual is irrelevant for the task at hand. Furthermore, our findings underscore the utility of virtual-reality paradigms in investigating social perception within realistic, yet experimentally well-controlled settings, and how subtle behavioural adjustments of avatars can effectively guide users' attention in complex environments.
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I feel it is true! Emotion-Based Predictors of Photos' Authenticity Perception

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Photojournalistic images can convey a powerful message, shaping our understanding of the world. Our results indicate that even a real photograph could be considered fake without any suggestion other than asking a question; and that this effect varies depending on the viewers' political beliefs. What impacts the authenticity judgment is worth further exploring - in particular, the emotional load of the photo is believed to be an important factor. We have chosen 1000 contemporary (2014-2021) photographs from the European Press Agency database, depicting a variety of worldly events affecting the lives of people and societies (military conflicts, riots, humanitarian crises, natural disasters, etc.). A representative sample of 300 participants was asked to judge whether they consider each photo real or fake and to declare confidence in this decision (scale 0-50). Participants's political beliefs were assessed using the Political Beliefs Questionnaire while controlling for demographic characteristics. Then, the different sample of 600 participants was asked to evaluate photos on the valence and arousal dimensions using the Self-Assessment Manikin Scale and to assign the emotions they felt while viewing a photo. Participants' political beliefs were also measured. Finally, participants' Sensory Processing Sensitivity, the construct known to impact the emotional evaluation, was measured using the Highly Sensitive Person Scale. The results revealed that Anger, Compassion, Disgust, Excitement, Fear, Guilt, Hope, Pain, Sadness, and Tenderness significantly correlated with image authenticity. Left-wing people more often reported feeling Guilt and Shame, while right-wing people - Pain and Disgust. People scoring higher on Sensory Processing Sensitivity evaluated photos as more arousing and more often reported feeling Anger, Compassion, Fear, Pain, Regret, Sadness, Tenderness, and Hope. Our results indicate that emotions play a crucial role in judging the picture as real or fake. Moreover, individual differences and political beliefs predict reported emotions, emphasizing complex authenticity judgment factors.
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I (don't) see it in your face: Limited integration of context in dynamic emotion perception

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Recent accounts suggest that face emotion perception is driven by the observer's internal model of how the person's emotion will develop next. Indeed, studies demonstrate that the perception of briefly seen dynamic facial expressions is biased towards their predicted next steps, so that the expressions appear more pronounced than they really are. So far it is unclear whether this overestimation is driven solely by the available motion cues in the stimulus, or whether contextual information about the forthcoming emotion is also integrated. We adapted a representational momentum task, where participants were presented with a contextual cue (e.g., statement "I'll smile") and watched a neutral expression morph towards happy or sad. After the face disappeared mid-movement, participants judged whether a probe face with either a more pronounced or less pronounced expression matched the final expression in the morph. Across four experiments, we found consistent overestimation of facial expressions, suggesting that motion cues affect the perception of dynamic facial expressions. The effect of context, however, where there is greater overestimation for expressions presented with a congruent cue than an incongruent cue, was only obtained in an initial study. Subsequent studies attempted to replicate this effect by adjusting the experimental design to increase the reliance on contextual cues, such as increasing the duration of each frame (exp 2), increasing the gap between the morph and the probe (exp 3), or adding visual noise to the face (exp 4). However, the effect of audio on the face was not observed. This suggests that facial expressions are overestimated but it seems to be primarily driven by the perceptual input itself (i.e., facial motion cues). Modulation of contextual cues appears to be either non-existent or too small to be detectable with the current design.
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Perception of the Relative Size of Volumetric Shapes in Virtual Reality

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Research on size perception has focussed primarily on its interaction with egocentric distance to maintain size constancy. Less attention has been paid to factors influencing our ability to judge relative size under more natural conditions. Here, we evaluate the contribution of monocular and binocular depth information under conditions where observers passively view or actively engage with the stimuli. Stimuli were presented using a virtual reality (VR) headset. Participants (n = 15) viewed a virtual rendition of a children's shape-posting toy at a distance of 0.8 m. On a given trial, one of four size-matched shapes (triangle, square, pentagon, or clover) appeared beside the box for 4 s. The shape's size relative to its target slot was varied across trials using a method of constant stimuli with seven levels centred on the correct size. Participants indicated if the target shape was larger than the slot. In the first study, participants could not interact with the shape. In another experiment, the participants (n = 11) could pick up the shape with a tool and view it from different orientations for 5 s. Cumulative normal distributions were fit to individual data to calculate JNDs and PSEs and averaged across observers. We found that size discrimination was accurate across conditions; PSEs were close to, but slightly less than a size ratio of 1. As expected, JNDs were consistently lower in the binocular viewing condition for both passive and active conditions. The ability to interact with the objects only slightly improved performance in the monocular conditions despite the addition of motion-based shape information. In ongoing studies we are evaluating the role of individual sources of depth information and shape complexity. The results highlight the importance of stereopsis in judgements of relative size for natural stimuli.
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Augmented Identity: Unveiling the Influence of Cybernetic Enhancements on Personality Perception

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Human enhancement denotes using embodied technologies to improve human capabilities. One of the oldest references to this adaptation of ourselves, instead of the environment, is the infamous "Cyborg," which relies on visible cybernetic implants. However, research into the augmentation of humans through cybernetic implants, particularly, our knowledge about the perception, evaluation and impact of such adaptation is scarce. In our experiment, 198 participants assessed facial stimuli either modified through cybernetic implants, tattoos, or piercings on the dimensions of intelligence, attractiveness, humanness, warmth, trustworthiness, and threat. Non modified facial stimuli were used as control. We found that individuals modified through human enhancement technologies were perceived as less attractive, warm, trustworthy, and human compared to non-modified individuals if severe modification was used. At the same time, they were perceived as more threatening. Results did not indicate an influence of cybernetic modification on intelligence. Tattoos appear to have significant negative effects on all dimensions, depending on their severity. No effect could be found for gender, ethnicity, or the modification through piercings. Besides connecting to established research on body modifications, our study provides an initial perspective on the social perception of cybernetic implants. Possible implications for social and economic questions are also discussed. The future will tell whether the phenomenon we examined is science-fictional or becomes cyborg reality.

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Both central tendency bias and serial dependence affect judgements about orientation and hue

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Perceptual decisions can be biased towards the immediately preceding stimuli (serial dependence) and towards the mean of all stimuli (central tendency bias). We studied the coexistence and relative magnitudes of serial dependence and central tendency bias in the perception of orientation and hue. In each trial, the observer was presented with a low contrast Gabor patch (orientation experiment, n = 12) or a coloured disk (hue experiment, n = 12) for 500 ms, followed by a probe stimulus. The observer adjusted the probe orientation or hue to match the first stimulus. Stimulus values were drawn from a truncated normal distribution. The distribution was centred at 45 degrees clockwise from vertical (orientation) or at the individually calibrated blue-green category border (hue). When response errors were analysed separately for serial dependence and central tendency bias, we found both: responses were biased toward preceding stimuli and the cumulative mean of stimulus values. When controlling for central tendency bias, however, the magnitude of serial dependence on the 1-back stimulus diminished significantly (hue) or disappeared (orientation). Controlling for 1-back serial dependence had little effect on central tendency bias. Further, linear mixed models using the cumulative mean, eight previous stimuli, and the starting value of the probe as predictors revealed that the cumulative mean and two preceding stimuli explained most of the biases in the responses for hue, and the cumulative mean and 2-back stimulus explained biases for orientation. The magnitude of central tendency bias was at least 2-fold compared to the bias caused by serial dependence. Finally, the starting value of the probe stimulus also caused a significant attractive bias. In conclusion, both central tendency bias and serial dependence from past stimuli have attractive effects on perceptual decisions about orientation and hue. Both should be accounted for when studying the effects of stimulus history.
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Characterising time-on-task effects on oscillatory and aperiodic EEG components during visual task performance

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Fluctuations in oscillatory brain activity have been shown to co-occur with variations in task performance. More recently, part of these fluctuations has been attributed to long-term (>1hr) monotonous trends in the power and frequency of alpha oscillations (8 – 13 Hz). Here we tested whether these time-on-task changes in EEG activity are limited to activity in the alpha band and whether they are linked

to task performance. Thirty-six participants performed 900 trials of a two-alternative forced choice visual discrimination task with confidence ratings. Pre- and post-stimulus spectral power (1-40Hz) and aperiodic (i.e., non-oscillatory) components were compared across blocks of the experimental session and tested for relationships with behavioural performance. We found that time-on-task effects on oscillatory EEG activity were primarily localised within the alpha band, with alpha power increasing and peak alpha frequency decreasing over time, even when controlling for aperiodic contributions. Aperiodic, broadband activity on the other hand did not show time-on-task effects in our data set. Importantly, time-on-task effects in alpha frequency and power explained variability in single-trial reaction times. Moreover, controlling for time-on-task effectively removed the relationships between alpha activity and reaction times. However, time-on-task effects did not affect other EEG signatures of behavioural performance, including post-stimulus predictors of single-trial decision confidence. Therefore, our results dissociate alpha-band brain-behaviour relationships that can be explained away by time-on-task from those that remain after accounting for it - thereby further specifying the potential functional roles of alpha in human visual perception.
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Audio-visual integration during knowledge activation in real-world scene processing

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In everyday life, auditory and visual inputs are combined and may influence each other's processing. We studied how non-verbal sounds may influence visual information gathering from real-world scenes and knowledge activation about them. Participants judged, as quickly and accurately as possible, which of two words referred to an action typically performed in the scene that followed. The scene was initially presented filtered by low or high spatial frequencies, providing mainly global or local visual information, and gradually changed into a full-spectrum image. A sound semantically consistent or inconsistent with the scene was presented for the whole scene duration. Compared to a no-sound baseline condition, accuracy was lower with an inconsistent sound but no different with a consistent sound, while correct responses were quicker with a consistent sound but no difference in response times emerged with an inconsistent sound. These results were found regardless of the spatial frequency filter. They suggest that non-verbal, auditory inputs modulate understanding of visual scenes, but their inconsistency or consistency might impact different mechanisms, namely likelihood versus promptness of activation of appropriate knowledge, especially when visual information is incomplete.

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Around the Clock: Physiological Markers of Lapses in Attention During Sustained Task Performance

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Too often still, people lose their lives or livelihoods in tragic accidents that have their root causes in lapses of attention. With today's technology, the development of assistance systems which can detect attentional lapses and prevent such accidents should be viable. One way to achieve this is to use objective, physiological signals in which sudden changes may indicate an imminent lapse. Our study aims at identifying physiological markers that are maximally diagnostic and reliable. We simultaneously record electroencephalographic (EEG) activity and changes in pupil size as we monitor performance in modified versions of two sustained attention paradigms: the Mackworth Clock Task and the Sustained Attention to Response Task. In both monotonous tasks, participants are required to stay focused for a long period of time and respond appropriately to infrequent target events. Preliminary results thus far support our preregistered predictions: in the seconds preceding a miss (or misresponse) – when we assume that participants were not paying attention – we observe an increase in activity in the alpha frequency band (8-14Hz) in occipital electrodes, a marker previously associated with attentional focus, and a difference in pupil diameter, a marker previously associated with neuromodulatory arousal. Furthermore, we observe time-on-task effects in both the EEG and behavioural data: a steady increase in alpha power and reaction time as participants generally become fatigued. Further analyses will target other measures such as the spectral slope of the EEG power spectrum that indexes excitability fluctuations and how different measures can be combined to increase reliability. Finally, comparing the data between the two tasks will provide insights into how much any given diagnostic marker generalises across situations with different response demands.
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Evaluation of region-of-use in spectacle lenses with eye-tracking technology

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Identifying areas of clear vision in ophthalmic lens design, particularly for presbyopic progressive power lens (PPL) wearers, enables precise design adjustments, leading to enhanced visual quality and wearer comfort. The aim of this study is to determine the vertical position-of-use, (VPU), defined as the vertical distance from the fixation mass center, projected on the back surface of the lens, to the fitting cross when wearing single-vision (SV) and PPL during distance and intermediate tasks, analyzing variations in positions on the lens depending on required addition (Add). Pupil positions of 15 subjects, divided into 3 groups (G1, 5 non-presbyopic subjects; G2, 5 subjects with Add≤2D; G3, 5 subjects with Add>2D), were recorded using an Eye-Tracker (ET, Tobii-Pro-Glasses3, Sweden; 50Hz). Subjects performed a distance task consisting of finding specific information on an airport departure board (20 trials) displayed on a TV (3.73m; 16.5x28.4deg) and an intermediate task consisting of filling up a questionnaire using a computer (0.70m;32.8x53.2deg). The tests were performed wearing SV (Endless Single-Vision, IOT) and wearing PPL (Essential Steady, IOT) with Add=2D for G1 or as prescribed for G2&G3. It was performed independent samples t-test for group comparison and paired t-test for lens comparison, setting p-value at

0.05. Average VPU for each group was G1: 3.2±3.9mm&-3.1±3.8mm for distance and intermediate task respectively, G2: 1.2±2.7 mm & -14.7±2.7 mm and G3: -0.9±2.9 mm & -18.3±4.2 mm. VPU was lower during the intermediate task compared to the distance task for 3 groups ($p<0.05$). For the intermediate task, G2&G3 used a lower zone compared to G1 ($p<0.05$). Furthermore, considering the lens type, G2&G3 look through a lower zone when wearing PPL compared to SV ($p<0.05$). The wearable ET method identified differences in regions-of-use influenced by visual tasks, prescribed addition, and lens type, providing valuable insights for improving the power distribution in PPL designs.

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Probing object and scene meaning in visual search: a quasi-experimental approach

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Efficiently locating objects within visual scenes is crucial for everyday behaviour. Here, we report results from a large-scale project where we utilised a quasi-experimental approach to investigate scene guidance during visual search in naturalistic environments. The stimuli consisted of 170 real-world scene images, each with a single target object that was a natural part of the scene. To capture different aspects of object and scene meaning discussed in the literature, two independent rating studies were conducted online. First, human observers rated each search object regarding (a) the likelihood of encountering this object in the scene (semantics) and (b) its positional fit in the scene (syntax). Second, to gauge the spatial distribution of semantic features within each scene, a 'meaning map' was generated by aggregating ratings on the meaningfulness of scene patches. Global scene meaning was defined as the mean value across all pixels in the map, while local meaning was represented by the mean value over the search object. Additionally, we determined the object's size and visual salience. Next, we conducted an eye-tracking study where 54 observers located the target object in each scene by directing their eyes to it. The main dependent variable was the latency to first fixation on the target, measuring how efficiently attention was guided towards it. Linear mixed-model analyses revealed independent effects of local meaning, syntax, and object size, indicating shorter latencies, and thus more efficient search, for higher-meaning targets, targets appearing at more probable locations, and larger targets. Moreover, latencies increased as global scene meaning increased, indicating that the increased presence of distractor elements in the scene slowed down search. In summary, the results suggest that both scene-based and target-based factors affect scene guidance during visual search. We discuss our findings in the context of existing research using experimental manipulations.

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Effect of discrete and continuous movements on visual time perception

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Background: Visual time perception (VTP) is crucial to successfully interact with the surrounding environment. VTP is altered when concurrent action is performed. The magnitude of the alteration depends on action parameters (e.g., timing, speed, duration, direction). Motor control theories suggest that action can be distributed into two classes, namely discrete and continuous movements. This study investigated the influence of movement types on VTP. Methods: Two groups of participants had to evaluate whether a moving disc reappeared from occlusion too early or too late while performing (or not) an action. The continuous group had to perform a continuous elbow extension from the moment the disc started moving until trial ends. The discrete group had to press a key when the disc reached the position it would have had 0.75s after occlusion (displayed on screen with a green target). For each action condition, individual psychometric function was computed to determine the Point of Subjective Equality (PSE) and Just Noticeable Difference (JND) which respectively reflect the accuracy and precision of the VTP performance. ANOVAs were performed on PSE and JND to evaluate the effects of Action conditions (Action vs. NoAction) and Groups (Continuous vs Discrete). Result: A significant interaction Group x Action Conditions was revealed on PSE. Post-hoc tests showed that PSE was modulated by Action Conditions only for Discrete Group, with higher PSE for the Action condition compared to NoAction condition. No significant effect was revealed on JND. Conclusion: Discrete movements, rather than continuous movements, influence visual time perception. Discrete movements may require increased attentional resources and cognitive processing in comparison to Continuous movements, making observes more focused on the VTP.

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From movement vigor to "perceptual vigor": Eye movements alter the postdictive window of visual awareness

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Underneath any given percept is a series of temporal moments stitched together. For example, an event can occur at one moment t1 (say, one disc A passing another disc B), but will be perceived in a categorically different way (that disc A caused disc B to move) depending on cues that appear just moments after at t1+Δt. This is the phenomenon of postdiction, when cues after-the-fact (within a "postdictive window") can paradoxically influence immediate visual awareness of events. What dictates the size of the postdictive window? While accounts of visual awareness typically focus on what comes into awareness, here we propose a more active picture: that is, particular properties of visual actions, such as that of eye movements, may reach into and restructure conscious perception. In each trial, we manipulated the pace of saccades, such that we could reliably induce eye movements to traverse the same amplitudes in either a faster ("high-vigor": lower latency, higher peak velocity) or slower ("low-vigor": longer latency, lower peak velocity) manner. To measure postdiction, we used an established paradigm of causal capture (Choi & Scholl, 2006), in which observers watched discs pass each other, while a "context" causal launch occurred either right at the moment the discs fully overlapped or after increasing lags. We replicated the main effect, with the context launch eliciting perceived causality even when occurring after-the-fact. Remarkably, the postdictive window was broader in low-vigor trials, with increased reports of perceived causality even when the context launch occurred after longer lags. We suggest that at a low-vigor state, the visual system recalibrates to integrate information over longer time windows perhaps to

compensate for potential processing delays. The “vigor” of visual actions influences not only the pace at which information arrives, but also how such information is stitched together into the stream of experience.
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Measuring melanopsin modulation of V1 responses using fMRI

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Melanopsin cells in the retina are different to other classes of photoreceptor in that their function is not primarily image-forming. However, recent evidence suggests that melanopsin-driven signals influence vision, perhaps by modulating the outputs from cone photoreceptors, and there is also a debate as to whether they are able to stimulate V1 directly, or whether their influence is confined to subcortical pathways. A previous fMRI study from our lab found unusual time course responses in V1 for S-cone isolating stimuli: the response to a long period of S-cone stimulation was sustained and did not drop back down to baseline after stimulus offset (at 12 seconds), or even by the end of the 12 second off period. We hypothesised that this was due to an effect of lingering melanopsin activation, which is known to have a prolonged response relative to the cone photoreceptors, and is most likely to be activated by an S-cone isolating stimulus (over a luminance or L-M stimulus) because we did not explicitly silence melanopsin in that study. Here, we report results from a more controlled experiment with a custom-made multi-primary LED system in which participants saw S-cone isolating stimuli that also either activated or silenced melanopsin, as well as melanopsin-only stimuli (where the S-cones were silenced). Stimuli were presented in a block design, 15s ON / 30s OFF to allow time for a sustained response to return to baseline between conditions. Here we present preliminary results indicating that melanopsin-driven responses can be recorded from cortical area V1, with the S-cone melanopsin-active condition showing a more sustained time course after stimulus offset, than the S-cone melanopsin-silenced condition.
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Brief Non-Spatial Cues Facilitate Search Performance in Dynamic Environments with Robots

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Searching for a relevant target in cluttered and dynamic environments is a time-consuming and exhaustive task. Processing each object and discriminating from the distractors leads to long search times which increase with the number of objects. Particularly in time-critical situations where a person oversees multiple devices and tools, reducing the search time can significantly enhance the operator's performance. In laboratory experiments, spatially non-informative auditory cues that are temporally synchronized with a change in the visual target have been shown to massively improve search performance (pip-and-pop effect). Until now, the pip-and-pop effect has been rarely studied outside the laboratory mostly using auditory cues. Here, we examined how tactile, auditory, and audio-tactile brief signals affect search performance in a dynamic and cluttered real environment with robots. We created a bounded field on the floor (2m × 2m) containing 10 swarm-robots (Thymio II). The basic robot behavior was straight ballistic motion with a constant velocity (0.1 m/s). If the robot detected an obstacle (field boundary, another robot) it randomly changed direction. The participants’ task was to detect the stopping of a single robot which occurred in half of the trials at a random time point. Synchronous to the stopping (or at a random time point in trials without stopping), we presented a sound, a vibrotactile stimulus on the torso, both (duration 100 ms) or no cue. All of the cue conditions resulted in a decrease in reaction times compared to no cue. Furthermore, hierarchical drift diffusion model showed that the difference in reaction times can be explained by a change in sensory acquisition rate. We conclude that brief and non-spatial auditory, tactile, and audiotactile cues facilitate the visual search in dynamic and cluttered real environments.
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Does implicit prior information about compliance contribute to exploratory force control in active touch?

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The sense of touch provides crucial information when performing everyday life tasks, such as choosing a high-quality fabric or finding a comfortable pillow. When performing these tasks, people adjust their hand movements according to different haptic properties to obtain relevant information, e.g. they may indent or squeeze the object to assess softness (Lederman & Klatzky, 1987). In addition, prior information about the object can also guide exploratory movements. When people in a softness discrimination task are presented only with hard or only with soft stimulus pairs –providing implicit prior information about the compliance of upcoming stimuli- they apply higher forces to the hard stimuli. This force-tuning improves the perception. Here, we aim to reveal how and how quick such implicit prior information on compliance becomes accessible for exploratory control in softness perception. In two experiments participants were presented with hard and soft stimulus pairs in predictable patterns alternating between hard and soft pairs every 2, 4 or 6 trials, or the sequences of same-compliance trials were presented randomly as an unpredictable pattern. They were asked to choose the softer stimulus on each trial. We analyzed initial and second peak forces in each trial. We observed that participants tuned their forces by applying higher forces to hard stimuli when stimuli were presented in predictable sequences of minimum 4 or 6 same-compliance trials. Besides these predictive processes in force-tuning, we also observed immediate reactions to stimulus compliance in the trial sequence of unpredictable patterns and in second peak forces. Overall, we suggest that people can use anticipatory mechanisms to adapt force to

prior information about compliance when presentation conditions are stable, but also react in their force-tuning behaviour to directly preceding sensory information about stimulus compliance.
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Jade: a real-time, VR-ready gaze event detector

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A Gaze Event Detector (GED) is an algorithm that parses a time series of raw eye movement data into meaningful gaze events (aka oculomotor behaviours). The best-known, and most-researched, gaze events are fixations and saccades; there are also smooth pursuits (SPs), events caused by vestibulo-ocular and opto-kinetic reflexes (VOR and OKR), vergence shifts, and more. Blinks and winks are related behaviours, affecting eye movement data, and many GEDs include a blink detection algorithm. Many GEDs have been developed in the last 50 years; most popular are IVT, IDT and their extensions. Most of these are well suited to the experimental paradigms with the participant sitting in front of a flat stimulus display. Thus they often equate eye movement and gaze shift, disregard head movement, do not account for vergence changes,etc. Nowadays, eyetracking technology rapidly becomes a ubiquitous component of most XR devices. One barrier for an adoption of gaze analysis in XR is a lack of GED algorithms that deal with coordinated eye-head-body gaze movements, and complex 3D stimulus scenes. Ideally, such an algorithm would be implemented to work in real time, allowing for gaze-contingent research, and gaze-aided UI. We expand on our, previously published, two-tier taxonomy of gaze behaviours; and present an implementation that runs in real time, on several commercially-available VR headset models, streaming detected gaze behaviours via a popular LabStreamingLayer platform; at every incoming data sample from the eye tracker, a best guess at the current event is updated and sent out. We also present results from an ongoing validation study.

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The influence of task engagement on time perception

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Traditional models of time perception revolve around the concept of an internal clock, based on a linear relationship between perceived and actual elapsed time. This theoretical framework suggests that our brain tracks time through a sequential process of accumulating internal pulses. Additionally, the attentional allocation model suggests that when our attention is absorbed in cognitive tasks, we tend to underestimate the amount of time that has passed, as opposed to when we are focusing on the passage of time. Most of this research has been limited to short and predefined intervals of time, overlooking the nature of real-world tasks, where duration is not fixed, and their potential effects on time perception. Our innovative approach investigates the impact of task engagement on time perception by studying the relationship between the actual time dedicated to the task—without setting predefined intervals—and its perceived duration. Participants were engaged in a visual search task and, after finding the target letter among distractors, they had to estimate how much time it took to complete the task. The number of distractors was varied from 100 to 500 to explore the effect of increasing cognitive load on time perception. When engaged in the visual search, participants consistently underestimated time compared to when they were not performing any task, with a linear relationship between estimated and actual time, supporting traditional time perception models. Interestingly, while the time spent in the task increases with the number of distractors, the amount of underestimation is the same, suggesting that, in these experimental conditions, clock rate does not vary with task difficulty. In conclusion, our research highlights that when we are engaged in a mental task, our estimation of the time spent doing the task is shorter than the real duration of the task, regardless of different levels of cognitive engagement.

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"Oh They Can Draw!"- Does Representational Context Affect Viewers Judgement of Abstract Art?

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The perceptual features of art are not the only factors that influence how we judge a piece of work. One particular factor is the context in which the image is displayed. Previous work has considered this in terms of the environment (e.g. art gallery vs lab), but in the current study, we focus on the surrounding images. We hypothesised that seeing abstract art (often regarded as low effort, particularly by novice viewers) in the context of representational work (seen as higher effort) by the same artist might lead viewers to judge the abstract art differently, as it was shown in the context of a more 'objective' demonstration of the artists skill. Sixty-eight participants in the current study rated examples of abstract art in either abstract or representational contexts, in terms of the perceived effort involved in creation, associated value, and how much they liked the work. However, results showed a significant effect only for liking, such that abstract art was less liked when displayed alongside representational works by the artist. These findings suggest a role for display context in aesthetic judgements, but that, at least in the eyes of novice viewers, abstract art may suffer in comparison to representational works.

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Pattern motion and optic flow analyses automatically acquired by decoding self-motion during natural motor actions

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Humans control various interactions with the external world heavily relies on visual information. We need to control our movements in real time considering self-body motions to access external objects. We previously hypothesized that illusory self-motion estimated from

visual motion triggers a quick manual response named manual following response (MFR). This hypothesis has been supported by our study showing that the spatiotemporal frequency tuning to visual motion of the MFR is similar to that of a convolutional neural network (CNN, 6-conv layers with last linear layer) trained to estimate self-motion (three translational and three rotational velocities) from first-person perspective image sequences in daily actions. To reveal the internal representation of the CNN, we first examined the specificities of pattern motion analyses by calculating pattern and component selectivity using grating and plaid motion. As observed in V1 and MT/MST cells in the hierarchical visual motion processing, many CNN kernels in the lower layer exhibited high component selectivity index, but this index decreased in the higher layer kernels while pattern selectivity tended to increase in the higher layer kernels. Interestingly, when tuning of each CNN kernel to the 3D optic flow was examined by feeding various translational and rotational dot motions in 3D space, we found that kernels in the 6th layers tended to be highly correlated with either component of the self-motion velocities. Additionally, the distribution of directional preferences looked similar to that in MST which is thought to contribute to perceptual performance of the flow direction. Importantly, without any explicit training of dot motion images, this CNN have successfully acquired the optic flow analysis only by training the self-motion decoding from image sequences. These results may imply that the visual motion analysis is shaped and maintained by estimating self-motion through interactions with the environment as suggested in the kitten developmental study.

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Insights into Antisaccade Performance and Motion Extrapolation in Hemianopia Patients

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Homonymous hemianopia is a condition in which patients lose vision in the same half of their visual field in both eyes due to a post-chiasmatic lesion, often located at the level of V1. For instance, a patient with a lesion in the right occipital cortex will experience loss of vision in the left side of the vertical midline in both eyes. Individuals with hemianopia frequently report greater difficulty in tasks such as watching videos compared to participants with normal vision. In this study, we aim to investigate how patients perform tasks involving saccades towards the sighted or the blind field in Experiment 1, and how they extrapolate the position of an object in motion that disappears within the blind field in Experiment 2. In detail, in the first experiment, patients completed a saccade and antisaccade task, wherein a bright spot appeared randomly in the sighted field and patients had to execute a saccade aiming at the symmetrical position of the bright spot in the blind field. In the second experiment, patients had to fixate a white cross while paying attention to a moving spot that disappeared behind their scotoma. After a variable period, the central cross changed its color, indicating the moment the target stopped moving. Patients had to estimate the position on the screen where the occluded target arrived with a mouse click. The precision of saccades and antisaccades in Experiment 1, as well as controlled fixation during target movement in Experiment 2, were measured using a Tobii Pro Spectrum eye tracker. A control group of healthy participants with artificial scotomas was included to compare patient performance. Results indicated poorer performance in both experiments among patients, suggesting an altered spatial map representation in the blind field region despite their prior ability to see in that specific visual field.

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Multicenter Assessment Pattern Reversal Visual Evoked Potentials in Children: Establishing Reference Intervals and Clinical Utility

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Checkerboard pattern reversal visual evoked potentials are essential for tracking vision and central nervous system development. Standardized protocols established by the International Society for Clinical Electrophysiology of Vision (ISCEV) enhance comparability across centers, which is crucial for clinical assessment and research. This multicenter study aimed to assess agreement between ISCEV Standard pattern reversal visual evoked potentials from three European centers, establish reference intervals across infancy to adolescence, and explore potential sex-based differences. Healthy infants and children (n=649, age: 2 weeks to 16 years) underwent pattern reversal visual evoked potentials recordings using similar protocols: checkerboards with large (50’/60’) and small (12’/15’) check widths, presented at 1-3.75 r/s, recorded from electrodes Fz-Oz. Analysis was conducted using orthogonal quadratic and sigmoidal curves. Results demonstrated comparability across centers and negligible sex-based differences. Pooled data revealed rapid decreases in P100 peak time, stabilizing by 27 and 34 weeks (‘critical age’) for large and small check widths, respectively. Post-critical-age reference limits were established as 87–115 ms and 96–131 ms for large and small check widths, respectively, alongside marked amplitude variations. The study confirms the feasibility of combining pattern reversal visual evoked potentials reference data despite slight methodological disparities within ISCEV Standards, supporting their robust clinical utility. The presented reference data provide a foundation for validation or adaptation in diverse settings, aiding clinical electrophysiological assessments of vision and neurodevelopment.

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Feature- and motor-based temporal predictions differentially benefit visual search performance in dynamic settings

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Dynamic visual search poses many challenges for the cognitive system. Environmental regularities can help improve target detection. The benefit of regularities in the temporal domain have only recently been investigated. Here we ask 1) if these benefits extend to feature-temporally predictable targets and 2) whether we find these benefits in the absence of temporally predictable motor responses to targets. We used a novel dynamic visual search task where either target features, motor responses, neither, or both, varied predictably with time. Participants searched a dynamic display of coloured circles embedded with small shapes. The stimuli faded in and out of the display at different times over the course of each trial. Targets were blue or pink, not green, and had a rectangle on one side, not a triangle. Participants identified targets by quickly pressing a key corresponding to the side of the rectangle (left or right). Importantly, each target appeared at one of two times during trials, early or late. Participants were each assigned one of four regularity conditions: 'baseline' (each target colour and response was equally likely at each target time), 'feature-temporal' (target colour varied predictably with time, e.g., blue early/pink late, response did not), 'motor-temporal' (response varied predictably with time, e.g., left response early/right response late, colour did not), and 'feature-motor-temporal' (both colour and response varied predictably with time). We found a reaction time benefit compared to baseline for the feature-temporal, motor-temporal, and feature-motor-temporal conditions. This suggests participants used each time-dependent regularity to benefit their performance. Furthermore, reaction times in the feature-motor-temporal condition were significantly faster compared to the feature-temporal condition, but not the motor-temporal condition. Therefore, motor-temporal regularities, whether paired with feature-temporal regularities or not, benefitted performance most. This study underscores the utility of temporal predictions in guiding dynamic visual search behaviour.
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A comparative study of the perceptual quality and aesthetic attributes across Tone-Mapping Operators

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Tone-mapping operators (TMOs) are algorithms designed to convert high-dynamic range (HDR) images into perceptually similar low-dynamic range ones. In the present study, we designed three different psychophysical experiments to study the performance of ten TMOs. All experiments were performed in a controlled environment, and physical HDR scenes were designed to study perceptual properties of TMO-generated images. Crucially, these three experiments permitted us to compare (1) the TMO-generated images (a.k.a., tone-mapped images) between each other, and (2) these tone-mapped images against the real HDR scene. In the first experiment, participants evaluated the local relationships among different lightness patches distributed across the HDR scene. These relationships were measured in both the real HDR scene and the TMO-generated images. In the second experiment, the participants rated the visual similarity and the naturalness between TMO-generated images and the real HDR scene, presented side-by-side. Finally, in the third experiment, participants ranked TMO-generated images according to their aesthetics preferences. These data sets facilitated the construction of three different rankings, evaluating grayscale and intrinsic image properties conservation, faithfulness to reality, and aesthetic appeal. Notably, more recently developed TMOs showed a superior performance in preserving the existing local relationships between objects, as evidenced by the first experiment results. Furthermore, a strong correlation between faithfulness and aesthetic appeal was also observed.
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Elevated Peripheral Crowding in Pre-Perimetric Glaucoma Evaluated Using Eye-Movement and Manual Response Paradigms

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Peripheral visual crowding refers to the difficulty in distinguishing objects in the peripheral field of vision, particularly when surrounded by clutter or other visual stimuli. Previous research indicates that individuals with glaucoma experience heightened peripheral crowding. This phenomenon could serve as a useful indicator for evaluating the functional visual performance of glaucoma patients. Understanding peripheral crowding in glaucoma may provide insights into the difficulties these patients face in everyday activities, including driving and object recognition. However, current methods for studying peripheral crowding are time-consuming and attention-demanding. This study aims to examine peripheral visual crowding in individuals with pre-perimetric glaucoma and assess the potential effectiveness of eye-movement-based paradigms in evaluating peripheral crowding in this older population. The study involved 10 pre-perimetric glaucoma patients and 10 age-matched controls. Crowding magnitudes were assessed using 2AFC Eye Movement, 2AFC Manual, 6AFC Eye Movement, and Serial Search paradigms. These paradigms measured crowding magnitude using orientation discrimination thresholds. Moreover, assessment times and participant preferences were compared across paradigms. Our results showed that pre-perimetric glaucoma patients exhibited elevated peripheral crowding ($p = 0.03$), however, this was only evident in the manual 2AFC response paradigm ($p < 0.001$). The serial search paradigm, utilizing continuous eye movements, emerged as the fastest method for assessing the thresholds (all p 's < 0.05), yet could not effectively distinguish between glaucoma and control groups in terms of crowding magnitude ($p = 0.81$). Unexpectedly, the 6AFC eye movement paradigm proved challenging for both groups, possibly highlighting age-related difficulties in distributing attention. In summary, confirming elevated peripheral visual crowding in glaucoma, our findings emphasize the importance and complexity of effectively assessing peripheral crowding in elderly participants, including those with pre-perimetric glaucoma.
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Right in front of your nose: attention and decision making in dressage judging?

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Eyetracking technology is invaluable for comprehending human visual perception, attention, and decision-making, extending its utility to various sports, including dressage. Dressage, known for the harmonious interaction between horse and rider, relies heavily on judges to assess performance integrity and ethical training. Yet, little is understood about judges' visual focus during assessments. Twenty dressage judges, split between novice (N=11) and advanced (N=9) levels, evaluated two horse-rider combinations. Using Tobii Fusion (250Hz), their visual search behavior, Duration of Fixation (DoF), and Number of Fixation (NoF) were recorded across four areas of interest (AOIs): front of horse, back of horse, horse's feet, and rider. Analysis revealed significant within-subject effects across AOIs for DoF ($F(3, 236) = 73.06$, $p < .001$) and NoF ($F(3, 236) = 101.25$ $p < 0.001$), with interaction effects between AOI*judging level (DoF: $F(3, 236) = 73.06$, $p < .001$; NoF: $F(3, 236) = 6.71$, $p < 0.001$), indicating differing visual patterns among judges. Linear trends ($p < 0.001$) revealed judges focused significantly more on the front of the horse than on other areas. Quadratic contrasts (DoF: $p<0.001$; NoF: $p = 0.008$) highlighted how judges' expertise influences attention allocation across movements, notably novice judges directing more attention to the rider. The front of the horse emerged as the most salient area for all judges, with the rider gaining additional attention from novice assessors. These findings shed light on the nuanced distribution of judges' visual attention during dressage performance evaluation, offering insights into the cognitive processes underlying expert performance assessment in equestrian sports.
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Intergroup processes and the happy face advantage

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There is abundant evidence that emotion categorization is influenced by the social category membership of target faces, with target sex and target race modulating the ease with which perceivers can categorize happy and angry emotional expressions. However, theoretical interpretation of these findings is constrained by gender and race imbalances in both the participant samples and target faces typically used when demonstrating these effects (e.g., most participants have been White women and most Black targets have been men). Across three experiments, the current research used gender matched samples (Expt. 1), gender and racial identity matched samples (Expt. 2), and a manipulation of social context (Expt. 3), to establish whether emotion categorization is influenced by interactions between the social category membership of perceivers and target faces. Supporting this idea, we found the presence and size of the happy face advantage was influenced by interactions between perceiver and target social categories, with reliable happy face advantages in reaction times for in-group targets but not necessarily for out-group targets. White targets and female targets were the only categories associated with a reliable happy face advantage that was independent of perceiver category. The interactions between perceiver and target social category were eliminated when targets were blocked by social category (e.g., a block of all White female targets; Expt. 3). These findings support the possibility that contextually sensitive intergroup processes influence emotion categorization.

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Synthetic information processing: role of input and observer characteristics

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Over recent years there has been increasing interest in stable individual differences in sensory processing capacities. For instance, face identity processing ability is considered a largely untrainable and likely heritable facet of cognition. The available empirical evidence stems from studies using likenesses of real humans presented under varied conditions to record responses from different effectors and using a range of neuroscientific methods. With the rapid development of technology, and generative AI specifically, the question arises: (how) do stable differences in cognition relate to processing of synthetic identity information? In this talk, I will review recent work on deepfake detection and discrimination of synthetic and real facial identities. This work illustrates how vision sciences can exploit generative AI to inform machine models of human cognition.
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Configurations in Motion:

Investigating the Relative Impact of Stimulus Characteristics on Motion perception

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When asked to localize the onset or offset location of a dynamic moving object, systematic biases towards and against the direction of motion have consistently been observed (Fröhlich effect, Onset-repulsion effect, Representational Momentum effect, Offset-repulsion effect). Recent evidence (Merz et al., 2022) suggests that these biases systematically change with variations in stimulus speeds, and demonstrate a closely mirroring relationship between the perceived onset and offset changes. With the aim of replicating this fundamental finding, several experiments with diverse stimulus configurations were designed to investigate whether this pattern of results can be generalized across different stimulus configurations (varying stimulus size; radius of circular motion trajectory; target

presentation), and to analyze the significance of absolute and relative stimulus speed for this data pattern. Overall, the findings indicate a robust data pattern across varying stimulus configurations, and the results are discussed in the context of the recently introduced Speed Prior Account (SPA) of motion perception.
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Comparing functional performance effects of VR-simulated static and dynamic visual disturbances

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Background: VR and motion capture technologies have strong potential to measure changes in functional performance in visually-guided everyday tasks for e.g. visual impairment and neurological disorders. Here we examine the efficacy of this approach using a virtual obstacle course to measure functional performance across different simulated visual disturbances. Method: 28 participants wore a Meta Quest (Reality Labs, Meta Platforms) Head Mounted Display with head, shoulders and feet tracked via an 8 camera OptiTrack motion capture system. Participants completed a virtual 60m course involving stepping over and squeezing between 6 obstacles on each of 13 trials. Trials 1-5 involved no visual disturbance and performance metrics recovered on trial 5 were used as a baseline. A further 8 trials involved VR-simulated static (e.g. High Blur - HB, Low Contrast - LC, Tunnel Vision – TV) or dynamic (e.g. mild & severe Horizontal Nystagmus - HN, mild & severe Mal de Debarquement - MdD) visual disturbances. We measured a range of performance characteristics including time to complete, gait speed and virtual obstacle collision count. Results: After confirming that time to complete stabilised over trials 1-5 (median = 56.2s) we found that performance varied markedly over disturbance conditions, with TV and MdB respectively leading to a particularly marked increases in median time to complete (39% & 25%) and mean number of obstacle collisions (115% & 189%) as well as decreases in mean gait speed (25% & 16%). Conclusions: This approach offers a promising, safe method to characterise visually-guided action performance. In future work, this will enable us to quantify: i) the extent to which performance changes in clinical conditions and how such performance might (or might not) relate to lower-level visual impairments; ii) the efficacy of new therapies designed to minimise symptoms and improve perceptually guided action.
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A hierarchical efficient Bayesian observer model predicts attractive and repulsive history effects in multistable perception

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In multistable dot lattices, the orientation we perceive is attracted towards the orientation we perceived in the immediately preceding stimulus and repelled from the orientation for which most evidence was present previously. Theoretically-inspired models have been proposed to explain the co-occurrence of attractive and repulsive history effects in multistable dot lattice tasks, but these models artificially induced a direct influence of the previous trial on the current one, without detailing the process underlying such an influence. We conducted a simulation study to test whether the observed attractive and repulsive history effects could be explained by an efficient Bayesian observer model, which has previously been applied successfully to different tasks involving non-ambiguous stimuli. The efficient Bayesian observer model assumes variable encoding precision of orientations in line with their frequency of occurrence (i.e., efficient encoding). It also takes the dissimilarity between stimulus space and sensory space into account, which leads to different outcome predictions depending on the levels of external stimulus and internal sensory noise. A direct implementation of the efficient Bayesian observer model could not predict the empirically observed attractive effect of the previous percept, but a slightly adapted version of the model including both stimulus history and perceptual history was able to explain the co-occurrence of both attractive and repulsive temporal context effects. Furthermore, this model could reproduce the empirically observed strong positive correlation between individuals' attractive and repulsive effects, by assuming a positive correlation between temporal integration constants for stimulus history and for perceptual history. To conclude, the study brings evidence that efficient encoding and likelihood repulsion based on stimulus history can explain the repulsive context effect, whereas prior attraction based on perceptual history can explain the attractive temporal context effect in multistable dot lattice perception.
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Saccade execution and inhibition shorten the perceived duration of peripheral stimuli

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A number of studies have demonstrated that the perceived duration of short stimuli decreases with stimulus eccentricity. Participants in these studies were required to maintain fixation on the screen center during stimulus presentation, thereby inhibiting saccadic eye movements towards the stimulus. Studies have shown that executing saccadic eye movements towards a peripheral stimulus distorts its perceived duration. Additionally, there are indications that the distortions of perceived timing of a stimulus that elicits a saccade compared to stimuli observed passively are due to saccade programming, not execution. The aim of this study is to investigate the perceived duration of peripheral stimuli when observed passively (Experiment 1) or when a saccade towards it is executed or inhibited (Experiments 2-4). In a series of four experiments, subjects performed a temporal bisection task categorizing the duration of a black disc as either short or long. The disc was presented for 20-220 ms at 6° or 12° of eccentricity left or right from fixation on the horizontal meridian. Eye movements were recorded using an Eyelink 1000 Plus. In Experiment 1, participants were instructed to either maintain

their gaze on a central fixation cross (control condition) or execute an eye movement towards the disc in a block-wise manner. Block order was counterbalanced across participants. In Experiments 2 and 3, we employed a go/no-go paradigm and varied the instruction to either execute an eye movement or maintain fixation on a trial-by-trial basis. The results indicate that perceived duration decreases as stimulus eccentricity increases, replicating previous studies. Additionally, perceived duration decreased when executing an eye movement compared to the control condition. Inhibiting the eye movement appeared to amplify this effect. The findings are discussed in relation to eye movement programming and potential interference effects introduced by the dual-task requirements of the go/no-go procedure of Experiments 2-3.

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Foveal feedback effects in an offset discrimination task with flanker interference

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The foveal feedback hypothesis proposes that during peripheral object recognition there is a representation of the object in the foveal cortex. This idea challenges traditional views, suggesting the existence of a non-retinotopic feedback mechanism. Behavioral studies have confirmed that a foveal mask disrupts performance in peripheral object recognition tasks. In this study, we investigated two aspects of foveal feedback: its role in a visual acuity task and the impact of flankers in the fovea. Participants judged the offset of a Vernier presented in the right periphery (12 degrees), while a foveal mask was introduced at various stimulus onset asynchronies (SOAs) after target onset, ranging from 0 to 250 milliseconds. Experiment 1 employed a colored dynamic patch as mask, akin to traditional foveal feedback paradigms. Experiment 2 simplified the mask to two vertical lines. By doing so, we reduced the complexity of the mask while maintaining it relevant to the task, as the peripheral presentation of vertical lines alongside the Vernier stimulus induces crowding. Our study tested two hypotheses: first, if foveal feedback is generalizable to a visual acuity task, higher threshold values should be observed within the 50-150ms SOA range, where foveal feedback is typically effective. Second, if flankers affect performance, similar threshold increases should occur regardless of type of foveal mask. The results indicate an increase in thresholds within the 50 to 100 ms SOA window during a visual acuity task. Notably, this peak is detected with both types of masks. Our findings suggest that foveal feedback might represent a general aspect of peripheral visual processing. They also highlight an interference similar to that taking place in crowding from non-overlapping stimuli.

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Colouring words with gaze: A novel approach to enhance reading skills in beginner readers

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Beginner readers often place their finger under the text while reading. Such finger-point reading supports directing attention to the relevant word, and facilitates returning to the appropriate in-text location when losing track. In the current study, we aimed to provide similar reading support by highlighting the text based on the reader's eye movements, and tested the effect on children's reading performance. Seventy native Danish-speaking children (age 8-9 years) read aloud a four-paragraph story from a computer screen. We varied the highlighting of words (without versus with) within subjects while measuring eye movements, literal reading comprehension, and highlighting preference. When children read without highlighting, black words were presented. With highlighting, black words turned blue once 'touched' by the reader's gaze. Our results revealed shorter reading times with versus without highlighting. In particular, highlighting compared to no highlighting was associated with fewer regressions and less time spent re-reading. Importantly, text comprehension did not significantly differ when reading with (84% accuracy) versus without highlighting (90% accuracy). Despite faster reading with than without highlighting, children strongly preferred reading static black text (61.4%) over text changing colour (26.3%). Our results suggest that regardless of participants' preference for the more familiar reading condition, gaze-based highlighting significantly enhances reading efficiency among beginner readers by reducing re-reading without impairing text comprehension. Our findings highlight the potential of gaze-based interventions as a valuable tool for supporting the development of reading skills in beginner readers.

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The relationship between Multiple Object Tracking and cognitive task performance in children and adults

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Attentional control plays an essential role in learning and academic achievement. Here, we aim to understand the developmental trajectories of the relationship between attentional control, measured with the Multiple Object Tracking (MOT) task, and cognitive sub-tests of the Wechsler Intelligence test, which measure the ability to reason and solve novel problems, such as puzzle solving, figure weights, matrix completion and an arithmetic task. One hundred twenty-four adults (M = 22 years, SD = 6.2; range:18-58 years) and 40 children (M = 8 years; SD = 1.6; range: 6-11 years old) performed a Multiple Object tracking task in which they were asked to track visually indistinguishable objects which initially were marked as targets among distractors. Furthermore, all participants were asked to perform a matrix reasoning, a visual puzzle, figure weights, and an arithmetic task as part of the Wechsler Intelligence test. Results indicate that adults with a higher MOT performance show better performance in subtests that require abstract reasoning measured by the Figure Weights task, puzzle solving, and arithmetic task performance. However, MOT performance did not correlate with a figure completion task (Matrix Reasoning). Similar as in adults, children with a higher MOT performance also showed a better performance in solving visual puzzles even when controlling for age. All other subtests did not show any significant correlation with MOT when controlling for age. These data suggest that multiple object tracking is related to other cognitive tasks, which load on non-verbal reasoning and fluid

intelligence. The findings substantiate the viewpoint to apply attentional control tasks as cognitive training tools to enhance higher-level cognition.

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Defining a functional hierarchy of millisecond time: from processing to perception

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In the human brain, millisecond durations of visual events are processed across different regions, from early visual to parietal and frontal areas. Previous functional magnetic resonance imaging (fMRI) studies have shown that early visual areas respond to durations via monotonic tuning, while downstream areas employ unimodal tuning. However, whether and how the properties of unimodal tuning change along the hierarchy to mediate duration perception is still unknown. In this study, we recorded brain activity at 7T-fMRI while participants performed a duration discrimination task of visual stimuli. We then modeled BOLD responses using the population receptive field approach for estimating vertex-wise tuning functions. Results showed that neuronal populations in occipital visual areas maximally respond to long durations, in line with the presence of monotonic tuning mediating duration encoding. In parietal, premotor and caudal supplementary motor areas, neuronal populations show selectivity to different durations, covering the entire presented range, and they are also spatially organized in maps. Both properties are compatible with the read-out of temporal information. In rostral supplementary motor areas, inferior frontal cortex and anterior insula, neuronal populations selectively respond to the mean of the presented durations. This selectivity also correlates with behavior, suggesting a subjective representation of temporal information used to solve the task. Our results also showed the existence of specific dependencies between these kinds of neuronal populations, highlighting three distinct functional units: occipital areas; intraparietal, insular, and inferior frontal areas; inferior parietal, supplementary motor, and premotor areas. These results suggest a putative functional hierarchy of visual temporal processing, where different areas may accomplish different contributions to duration perception. They also shed light on the neural basis of the subjective experience of time, suggesting that it may be rooted in the fundamental tuning properties of brain responses.
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Paradigm-dependent isolation of perceptual correlates with fMRI

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Perception is not a direct reflection of physical reality. Instead, it emerges from a combination of sensory inputs, the detectors encoding them, and cognitive processes. Disentangling these signals in the brain is an important challenge for understanding the mechanisms of conscious experience. To address this challenge, we combined a two-tone image paradigm with functional magnetic resonance imaging (fMRI). Two-tones are ambiguous images that become easily recognisable following cueing with the original photo version. Presenting two-tone images before and after a photo cue therefore elicits distinct perceptual experiences to identical visual inputs, a process known as perceptual reorganisation. In this way, we can separate the contributions of sensory input and prior knowledge to perceptual experience. While previous research has used this approach to identify brain areas representing knowledge-driven percepts, methodological differences resulted in inconsistent findings. To resolve this, we assessed the efficacy of different fMRI paradigms in isolating neural signals corresponding with perceptual experience across the visual hierarchy. We found that variations in fMRI run design significantly impact the measurement of the perceptual reorganisation effect. Specifically, multivariate pattern analysis (MVPA) of brain areas representing perceptual reorganisation was strongly affected by how consecutive image conditions (naïve two-tone, photo cue and cued two-tone) were split within and across runs. This reveals that depending on task design, fMRI can capture different aspects of the neural signal and their contributions to stimulus-driven versus knowledge-driven representations. Any study investigating how the perceptual effects of repeated stimulus presentations must therefore consider these dynamics to ensure accurate and consistent identification of neural representations.

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Adaptation leads to faster reaction times in a face search task

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Adaptation to faces can strongly bias the perceived characteristics of subsequently seen faces, but has been found to have relatively weak effects on tasks such as face discrimination. We examined the impact of prior adaptation on the salience of face stimuli, by using a visual search task. Participants adapted for 12 seconds to grayscale images of Asian faces that slowly morphed between different identities. To control for low-level aftereffects, the adaptor was shown at the center of the screen and was 1.25x larger than the test faces, which were arranged in a circle in the periphery. The test array included images of 5 Asian distractor faces and a 6th target face formed by morphing between a White and Asian face. Target salience was controlled by varying the morph level from 20% to 50% White in steps of 10%. In a second, 2-AFC discrimination task using 2-down 1-up staircases, we also measured the effect of brief adaptation on discrimination thresholds for 3 reference faces that contained 100%, 75% and 50% Asian, respectively. Brief 12s adaptation to the Asian face images induced significant aftereffects, shifting the Asian-White category boundary in the morph toward the Asian direction. This adaptation also reduced reaction times for detecting the target face in the search task for all of the tested morph levels, but had minimal effect on discrimination thresholds or search accuracy. Similar effects on visual search and discrimination performance were found after 20 mins of face adaptation in a new group of participants. Across these two adaptation durations tested, our results provide evidence

that face ethnicity adaptation heightens the salience of target faces that differ along the ethnicity dimension, potentially because the adaptation renormalizes the adapting ethnicity so that it appears more neutral and therefore less distinctive.

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GramStatTexNet Extended: Evaluating the Relative Importance of Gram Matrix Statistics for Texture Models

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Human visual area V1 is often modeled with multi-scale, oriented filters which are combined together via higher brain regions to represent visual information, including both texture and peripheral visual processing. To determine how these filters should be combined, manual testing and psychophysical evaluation has been used to evaluate the necessity and sufficiency of various statistics for representing textures as well as creating mongrels/metamers for peripheral vision. While the human vision science literature has focused on pre-determined statistical families, deep-learning approaches to texture and peripheral vision instead often utilize the Gram matrices of a network's inner layers, evaluating all of the cross-correlation terms for a layer's nodes. In this work, we combine these approaches by calculating the Gram matrix directly on the output of a multi-scale pyramid representation, and expand on previous work that used contrastive learning to evaluate the importance of statistical features. First, we develop a categorization strategy for pyramid gram statistics, grouping correlations between oriented pyramids while varying color channel, scale, orientation, and pyramid type (real/imaginary/magnitude). This enables the systematic inclusion and exclusion of families of statistics and comparison to previous work utilizing non-Gram-based statistics. We combine this categorization strategy with synthesis to evaluate the relative importance of various statistics families, quantifying this with perceptual similarity metrics. In addition, we use NTXentLoss/InfoNCE to improve results for contrastive learning that automatically identify the most important statistical families, and use synthesis to validate this.
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Testing Driver Monitoring Systems and Driving Distractions via a Customised Robotics and VR Setup

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Following recent developments in autonomous driving, particularly towards Level 4 (SAE), various driver monitoring systems have been proposed and developed. These systems are designed to monitor and understand human driving behaviours under complex driving scenarios, for both technical specifications in autonomous driving and legal requirements. The aim of the current study was to understand human behaviours in driving tasks under specific distractions. The experiment was conducted using a customised robotics setup, that included a multisensory driver monitoring system, a driving simulator, and a VR setup with the HTC VIVE. This setup allows us to have both eye-tracking and hand-tracking, and to collect physiological data such as heartrate and skin-conductance. We developed simulated scenes and testing conditions, and instructed the participants to perform in three driving modes, namely 1) aggressive-driving, where participants were instructed to drive as fast as possible, 2) safe-driving, and 3) distracted-driving, where we instruct the participant to drive safely in safe-driving mode, but provided distractions, such as visual (eye fixation off the driving scene), audio (talking), manual (hands off the wheel), or cognitive (performing calculation tasks) distractions. Participants found the driving tasks doable and comparable to the real-world driving. With unsupervised learning methods on the collected data, preliminary results showed that participants performed and reacted differently in the three test conditions. However, we did not found contributions from heartrate and skin-conductance in the extracted features of the clustered performances. The work will be continued by 1) further developing the sensors for sensitivities, 2) modelling human behaviours in our driving tasks. Eventually, the setup and the model could help improve the performance of the monitoring systems, and be integrated to autonomous vehicles to enhance the explainability and reliability. Furthermore, such systems will help reducing the public concerns about the safety and contributing to societal acceptances.
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Seeing gender stereotypes: The role of second-order head/facial features

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Human faces serve as windows to the intricated realm of social perceptions and interactions. We often rely on stereotypes to quickly frame people by looking at their faces. Focusing on the gender-science stereotype (GSS), we explored the visual weight of face/head features in attributing a specific STEM (science, technology, engineering and mathematics) competence, or lack thereof. The aim is to study basic mechanisms underlying gender stereotypes and the perceptual and cognitive dynamics that come into play when activating or enhancing GSS. Starting from a female head and a male head, a set of female (Exp.1) and a set of male heads (Exp.2) were created by modifying second-order features (i.e., beard, make-up, hair colour and length). A scientific and a literary text were associated to the heads of the two sets; participants' (N= 90) task was to evaluate the likelihood of the text's authorship on a 10-point Likert scale based on the head visualized. Results show a negative effect for blonde hair (''dumb blonde'' effect) for both genders, and for heavy make-up for females; a positive effect was found for glasses for both genders, and for beard for males. A Linear Mixed Model Analysis was run to explore the differences between scores for female and male heads. Results show that male heads received significantly higher scores in Science than female ones ($p < 0.001$), but scores relating to Literature were statistically equal ($p=0.82$). Overall, results suggest the existence of a gender bias. Results and interactions will be discussed in light of the perceptual elements at play to understand the interplay between cognitive and perceptual factors in activating the GSS.

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Different temporal dynamics of perceptual distortion of visual space inside and outside of objects

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Visual objects are known to distort the perception of space. For example, the distance between two dots placed inside an object appears farther apart (expansion effect), while the distance between dots placed outside an object appears closer together (compression effect). Although these effects seem to be two polar aspects of the same object-based spatial distortion, the extent to which these two effects share the common characteristics remains unclear. We investigated the temporal dynamics of the object-based compression and expansion effects by manipulating the stimulus onset asynchrony (SOA) from the object to the dots. In the experiments, we presented a rectangular object and the two dots, which were placed either outside or inside the object, with various SOAs. The results showed that, when the dots were inside the object region, the expansion effect was observed regardless of the SOA. However, the expansion effect was more pronounced at shorter SOAs. On the other hand, when the dots were outside the object region, the compression effect was observed when the dots appeared after and simultaneously with the object, whereas the expansion effect was observed when dots appeared before the object. Control experiments ruled out the possibility that the size of the object or the distance between the dots was the cause of these different temporal dynamics. These results suggest that different mechanisms underlie the compression and expansion effects.

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The detrimental use of redundant motion signals in car direction indicators

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Yellow indicator lights flashing on the left or right side of vehicles are crucial signals in road traffic, indicating a change of driving direction. Moreover, the simultaneous flashing of indicator lights on both sides serves as a warning signal, indicating an emergency. Expanding upon the traditional flashing signals, advancements in LED technology now allow for the integration of motion patterns into indicator lights. This addition provides a secondary, redundant signal to indicate a change in driving direction. Usually, the utilization of two redundant signals is advantageous, as it can expedite perceptual decision-making processes. Yet, the introduction of motion patterns reduces signal intensity at onset, a crucial factor influencing reaction time speed. To assess the efficacy of redundant motion patterns in road traffic signalling, we conducted a visual search experiment using sets of 2, 4, or 6 cars. Participants were tasked with detecting left/right indicator lights and responding with button presses using the corresponding hand. Furthermore, participants were instructed to respond to warning signals by pressing a foot pedal. We utilized both traditional flashing of indicator lights and added motion sequences in two versions. These motion sequences were categorized as either on-motion (starting with no light and gradually turning on) or off-motion (starting with full light and gradually turning off). While error rates demonstrate a marginal benefit in crowded scenes (6 cars), reaction times exhibit a significant increase across all set sizes for on-motion signals compared to both classical flashing and off-motion. Regarding emergency indicators, the addition of on-motion signals does not change error rates but does lead to increased reaction times. Thus, the utilization of on-motion signals in car indicator lights is detrimental. For car manufacturers considering the addition of motion signals as a gimmick, opting for off-motion sequences would be a superior choice from a signalling perspective.

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Perception of emotional states based on eye regions in 5- to 10-year-olds and adults

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The eye and mouth regions can be important sources of information for identifying emotional states, but how the relative influence of these regions changes over the course of development is not well understood. In particular, the ability to process facial expressions holistically and to determine whether a smile is true or not based on eye cues are known to develop gradually during childhood. We tested the ability to discriminate facial expressions for children aged 5-7 and 8-10 years and adults (N=20 respectively for each age group) with following face figures: Happiness, Happiness with neutral eyes in which the eye region of happy face was changed to neutral, Neutral with happy eyes in which the eye region of neutral face was changed to happy, and Neutral. The participants rated the arousal, valence, and attractiveness of the facial expressions by a visual analogue scale. A total of 24 face stimuli were used, six for each of three males and three females. If differences in eye regions affect the perception of emotional states, then there should be differences in arousal, emotional valence, and attractiveness between 'Happiness and Happiness with neutral eyes' and 'Neutral and Neutral with happy eyes.' The results showed that there were no significant differences in all rating values in either age group for Happiness and Happiness with neutral eyes, but for Neutral and Neutral with happy eyes, only in adults, Neutral with happy eyes rated higher arousal and lower emotional valence and attractiveness than Neutral. On the other hand, 5-7- and 8-10-year-olds did not show significant differences in arousal and emotional valence, but rated Neutral with happy eyes lower in attractiveness than Neutral. These findings suggest that adults and children differ in discrimination of facial expressions based solely on eye cues.

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The effects of colour desaturation of food images on approach behaviour

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The colour of food is a salient visual cue used to determine its freshness and quality. In a previous study, we have found that self-reported cravings and perceived palatability decrease when the colour of food images is partially or completely (i.e., grey-scaled) desaturated. Furthermore, the effects of desaturation were larger for perishable than non-perishable foods. Interestingly, while food images have been found to evoke reliable attentional biases, those biases have been found to disappear when food images are grey-scaled. However, it is unclear if this is also the case for human behavioural responses, i.e., approach biases. Here, we investigated if and how colour desaturation (grey-scale vs. natural colour) affects approach responses towards perishable and non-perishable food images. Participants (N=29) completed a Stimulus Response Compatibility (SRC) task with colour saturation of the images being varied in blocks and counterbalanced across subjects. Results showed a general approach bias to all food images independent of colour saturation and food type. Post-hoc analysis, suggested that the order in which participants completed the tasks affected the presence or absence of approach biases in the grey-scale condition suggesting possible transfer effects between conditions. Consequently, we ran a between-subject study in which different groups of participants (N=73) completed the SRC task in either the grey-scale or the natural colour condition to determine if approach biases truly persisted for grey-scaled images. The findings revealed that approach biases remained consistent for both food types and both natural and grey-scaled images which suggests that attentional and approach biases towards food may be mediated by different processes.

Symposium 3 - Space matters: Cortical traveling waves and their role in perception and attention

Cortical traveling waves and their measurement

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Cortical activity measured through various invasive and non-invasive means has been found to produce spatiotemporal patterns in the form of traveling waves in the sensor arrays. Relating waves observed in, e.g., magneto-/electro-encephalographic (M/EEG) recordings back to spatiotemporally propagating activity in the cortex requires multiple consecutive, but sometimes interchangeable processing, analysis and interpretation steps. Over the past decade, various theoretical models along with methods for the detection and classification of traveling waves have emerged. The current literature, however, still lacks consensus on traveling wave definitions as well as clear prescriptions of which analysis methods can and should be applied in specific experimental situations. Based on non-invasively recorded time-resolved data from human participants (concurrent M/EEG in 19 participants), I will illustrate how a traveling wave induced in visual cortex can be detected and analyzed in an extracortical sensor array and how experimental outcomes can strongly depend on the chosen analysis. I will demonstrate how WaveSpace, a new modular tool for the simulation, analysis and statistical evaluation of traveling waves, can be used to facilitate reproducible and common analysis pipelines. Building upon recent theoretical advancements and weary of potential pitfalls in the interpretation of spatiotemporal patterns observed at a distance form their cortical origin, WaveSpace implements a range of pipelines for the detection and analysis of traveling waves in a common computational framework, along with an extensive simulation module. Together, those tools allow researchers to model experimental outcomes in silico and finetune experimental paradigms and analysis choices before data collection.
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Forward and backward traveling waves reflect different cognitive processes during visual attention and working memory

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Alpha-band oscillations have been associated with a plethora of cognitive functions. Several studies demonstrated that visual attention increases alpha-band power in the hemisphere ipsilateral to the attended location, suggesting their involvement in inhibitory functions. Conversely, other studies positively relate the phase and the amplitude of alpha oscillations with visual perception. In this presentation, I will highlight the importance of considering the spatial component of oscillations (i.e., traveling waves) and their direction of propagation when disentangling their functional roles. In the first study, I will present EEG recordings of participants performing a covert visual attention task. Our results reveal two distinct processes: allocating attention to one hemifield increases top-down alpha-band waves propagating from frontal to occipital regions ipsilateral to the attended location, both with and without visual stimulation. Yet, different alpha-band waves propagate from occipital to the frontal areas and contralateral to the attended location, but only during visual stimulation, suggesting a separate mechanism related to visual processing. In a second study, we reanalyzed two open-access EEG datasets where participants performed lateralized delayed match-to-sample working memory tasks with different distractor loads and set sizes. Our results reveal an increase in alpha-band forward waves with a larger distractor load in the hemisphere contralateral to the distractors, and an increase in forward and a decrease in backward waves with larger set size and contralateral to the target location. Such a dissociation suggests the co-existence of bottom-up and top-down inhibitory processes: alpha-band forward waves might convey a secondary gating effect driven by distractor load, while backward waves may represent direct top-down gain control of downstream visual areas. Together, our results show that the propagation directions of oscillations characterize distinct processes in visual attention and working memory functions, demonstrating the importance of considering oscillations as traveling waves when characterizing their functional role.
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What can oscillation phase tell us about traveling waves - perspective from MEG

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Inter-areal phase-coupling of neuronal oscillations – phase synchronization – has been established to mediate neuronal communication between brain areas. In humans, phase synchronization of neuronal oscillations is quantified as statistically significant relative phase differences between oscillations in distant brain areas. Such phase-synchronization has been considered one of the most plausible candidate mechanisms for forming dynamic links among brain regions and thus for large-scale integration of the information. In recent years, the propagation of oscillations as traveling waves with systematic phase delays between brain regions has been considered as an alternative mechanism to synchronization Here, traveling waves are described as a gradient of phases throughout the sensory system. I will discuss the identification of inter-areal synchronization vs. traveling waves from human source reconstructed MEG data and what can we infer from oscillation phase differences and oscillations gradients across cortical areas. Our research shows that gradient of phases can also be created by distant oscillatory sources without propagating activity. In contrast, we propose a new approach for identification of traveling waves based on a novel phase-autocorrelation function. I will discuss findings in relationship with visual attention and perception.

Mapping neural mechanisms of travelling waves using MEG

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Growing evidence suggests that travelling waves are functionally relevant for cognitive operations in the brain. Several electroencephalography (EEG) studies report on a perceptual alpha-echo, representing the brain response to a random visual flicker, propagating as a travelling wave across the cortical surface. In our recent study, we ask if the propagating activity of the alpha-echo is best explained by a set of discrete sources mixing at the sensor level rather than a cortical travelling wave. To this end, we presented participants with gratings modulated by random noise and simultaneously acquired the ongoing MEG. We found that the propagation of the alpha-echoes was predominantly centro-lateral, while EEG studies reported mainly posterior-frontal propagation. Moreover, the propagation speed of the alpha-echoes derived from the MEG data was around 10 m/s, which is higher compared to the 2 m/s reported in EEG studies. Using source modelling, we found an early component in the primary visual cortex and a phase-lagged late component in the parietal cortex, which may underlie the travelling alpha-echoes at the sensor level. We then simulated the alpha-echoes using realistic EEG and MEG forward models by placing two sources in the parietal and occipital cortices in accordance with our empirical findings. The two-source model could account for both the direction and speed of the observed alpha-echoes in the EEG and MEG data. Our results demonstrate that the propagation of the perceptual echoes observed in EEG and MEG data can be explained by two sources mixing at the scalp level equally well as by a cortical travelling wave.

How travelling waves in the visual cortex participate in processing visual motion.

Frederic Chavane[1]
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Since the pioneering work of the Hubel and Wiesel, the visual system is mostly conceived as a feed-forward hierarchical flow of sensory information. Accordingly, low-level visual information (such as position and orientation) is extracted locally within stationary receptive fields and is rapidly cascaded to downstream areas to encode more complex features. Such a framework implies that processing at each level of the visual system must be fast, efficient and mostly confined to network of neurons with overlapping receptive fields. In recent work, however, we have demonstrated that any local stationary stimulus is, in itself, generating waves propagating within the early cortical steps of visual processing. Visual information thus does not stay confined to a particular retinotopic location but instead invades a large cortical territory, connecting neurons with neighboring receptive fields. What could be the computational advantage of cortical waves in the processing visual information? I will show that, in response to a temporal sequence of stimuli presented in different spatial positions along a trajectory, a long-range apparent motion stimulus, these waves collide and interact non-linearly. This non-linear interaction results in shaping the cortical representation of the apparent motion to encode motion signal within cortical retinotopic maps. I will propose that propagation of intra-cortical wave can subtend generic computations by which the visual system keep track of moving object but also generates predictions.
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Talk Session 5 - Perception & Action

Perception-Action Dissociations in the Garner Paradigm: Evaluating Evidence From Manual Size Estimation

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Certain stimulus dimensions like the length and width of a rectangle are considered integral in nature and cannot be processed separately. For example, when length and width both vary (filtering condition), participants are slower to classify rectangles along one dimension (e.g., width), as compared to a condition in which only one dimension varies while the other is held constant (baseline condition). This slower performance in the filtering condition is called Garner interference (Filtering – Baseline). An influential study reported for three-dimensional rectangular stimuli (cuboids) that Garner interference occurred in a traditional speeded-classification task and in manual size estimation (where participants indicated the width of the cuboids with their fingers), but not in visually-guided grasping (where participants grasped the cuboids along their width). This dissociation was taken as strong evidence for the Perception-Action Model, which suggests that visual information is processed in a fundamentally different way for perception (like speeded-classification and manual estimation) than for actions (like grasping); with vision-for-perception being attributed to the ventral cortical stream and vision-for-action to the dorsal stream. However, across four experiments including replications (total N = 110) and a meta-analysis of all existing studies, we found only small Garner interference in manual estimation. Instead, manual estimation behaved quite similar to grasping. Our experiments included systematic manipulations which were hypothesized to affect Garner interference, like

response amplitude and the availability of online visual feedback during the task (closed-loop vs. open-loop). However, none of these modifications introduced Garner interference in manual estimation to a level comparable to that of the traditional speeded-classification task. Our investigation suggests that Garner effects in grasping and manual estimation might be more similar than previously assumed and might not provide sufficient evidence for processing differences in perception and action as assumed by the Perception-Action Model.
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Scene gist: the rapid acquisition of information for grasping

Kimberley Stanford[1], Simon Rushton[1], Eli Brenner[2]
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If judging whether an object is graspable is a fundamental ability, as the idea of the perception of action affordances proposes, one might expect people to be able to make such judgments even when the object is viewed very briefly. That some judgments can be made after very brief exposure has been demonstrated for scene gist and face perception. We question whether action affordances are perceived similarly fast. We investigated how presentation duration influenced participants' ability to judge graspability of spheres. Participants (N=15) were asked whether a sphere, presented within reach on a tabletop, was graspable (could be picked up cleanly with one hand). Viewing durations were either 2000ms (considered equivalent to unlimited viewing), 150ms or 15ms. Participants made precise grasping judgements across all viewing durations. This could suggest that participants perceived grasping affordances remarkably quickly. However, the presence of lingering afterimages, or the use of simple correlates of sphere size (retinal size and the height of the sphere in the visual field) could also explain these results. To control for this, we conducted two follow-up experiments. One disrupted the relationship between the size of the sphere and its retinal size and height. The other experiment replicated this, while adding a visual mask to remove lingering visual persistence. Disrupting retinal size and height did not reduce precision. However, with the addition of a visual mask, some participants showed reduced precision on grasping judgements at 15ms compared to 2000ms viewing durations. Interestingly, despite an overall decline in precision at shorter viewing times, some participants still managed to make precise judgements with only 15ms of visual information. These findings suggest that humans can pick up information for the visual guidance of action very rapidly, comparable to that required to judge the form of a scene or faces.
Acknowledgements: Cardiff University School of Psychology; ESRC grant (ES/S015272/1).

Visually guided grasping survives large bilateral lesions of the occipitotemporal cortex: Behavioural and neuroimaging evidence

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Neuropsychological studies have described patients with spared grasping despite profound deficits in visual recognition with visual agnosia; however, one critique has been the scant number of cases. Here we investigate whether grasping is preserved even in a much more dramatic loss of visual processing in patient MC, who has large bilateral lesions encompassing most of the occipital lobes and much of the visual ventral stream. Despite such extensive lesions, MC demonstrates some spared visual function, particularly for motion (Riddoch phenomenon). We assessed MC on behavioural grasping and estimation tasks, a T1-(w)eighted anatomical scan (compared to one taken 15 years previously), and previously collected fMRI data comparing visually guided grasping and reaching. For the behavioural tasks, we manipulated the size and orientation (0 or 90 degrees) of 5 Efron shapes. During the estimation task, MC had to demonstrate (with the opening of her thumb and index finger) the width of the Efrons placed in front of her and could not do so. When asked to grasp and lift the Efron blocks, she showed clear grip scaling and incorporated the different sizes and orientations in her target approach. Visual inspection of the anatomical scan showed no deterioration or cortical atrophy over 15 years, despite the course of aging, not to mention the severe reduction in sensory input. Moreover, MC's spared grasping abilities were reflected in fMRI, where she showed grasp-selective activation in the left anterior intraparietal sulcus. These findings show that grasping abilities can be preserved even in the face of strikingly large lesions to early visual and ventral-stream areas. Grasp-relevant visual information is likely provided via subcortical routes to the dorsal stream that bypass the geniculo-striate pathway. We are currently analysing the T1(w) data for subtle volumetric alterations and new DTI data to further elucidate potential pathways that underpin her behaviour.

A new model of perceived weight: The size-weight illusion and beyond

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In the size-weight illusion, the smaller of two same-weight, same apparent material objects is perceived as heavier. This illusion has proved difficult to explain via traditional Bayesian models; these predict the opposite: a smaller = lighter expectation should be integrated with felt weight, such that the smaller object is perceptually lighter. Other authors have proposed that weight and density are perceptually confounded, or that Bayesian models incorporating efficient coding can predict the size-weight illusion via 'likelihood repulsion'. However, these models have only been evaluated under narrow conditions: generally, equal weight objects. We present psychophysical data, alongside a general model of perceived weight, for pairs of objects that differ in weight and / or density (and / or size) by varying amounts. In a visuo-haptic task, participants (N = 30) grasped and lifted pairs of cube stimuli, and reported their perceived heaviness. We report that the size-weight illusion occurs even with very small density differences, repudiating the idea that the illusion requires a significant conflict between expected and felt weight. Across all object pairs, perceived weight of a target object was well explained by a model (R^2 = .98) that includes a positive influence of the target and non-target weights and the target density, but a negative influence of the non-target density. Critically, the influence of both densities on perceived weight was strongly modulated by weight difference, being three times as large for zero / small weight differences than large ones. Thus, it is only under the unusual conditions of typical size-weight illusion studies that weight and density are confused / confounded to a substantial extent. Existing

models are inconsistent with our more comprehensive dataset. Our model provides a quantitative, accurate and generalised account of weight perception for pairs of objects across a variety of weight and size conditions.
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Is Visuo-Haptic Mental Imagery Related to the Strength of the Size-Weight Illusion?

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Mental imagery, the ability to imagine perceptual experiences without sensory input, putatively relies on emulation/prediction processes shared with sensory perception. In the size-weight illusion, expectations about how heavy objects of different sizes should feel give rise to highly consistent biases where smaller objects are perceived as heavier than larger ones of equal mass. Might this perceptual illusion also rely on mental simulation processes? To answer this, we developed a Haptic Imagery Questionnaire (HIQ) asking how vividly one can visually and kinaesthetically imagine performing different hand actions. We then administered the HIQ, alongside the established Vividness of Visual Imagery Questionnaire (VVIQ) to 130 participants. The same participants performed a size-weight illusion task where they reported the felt weight of two cubes of equal weight (125 g) but different sizes (125 vs 500 cm^3) under different conditions where they could only see (visual-cue), only feel (haptic-cue), or both see and feel (full-cue) object size. The HIQ exhibited good reliability (α=.83), correlated with VVIQ scores (r=.50, p<.001), and revealed that participants had more vivid visual than kinaesthetic imagery (p<.001). As expected, we replicated the size-weight illusion: small objects felt heavier than large objects of the same mass (p<.001). We also confirmed that the illusion is primarily driven by haptic size cues, as the illusion was weaker in the visual-cue condition compared to both full-cue (p<.001) and haptic-cue conditions (p<.01), which instead did not differ (p=.101). Illusion strength was correlated across visual and haptic conditions (r=.42, p<.001), indicating reliable individual differences which had an anthropometric correlate: taller participants experienced a weaker illusion (r=-.29, p<.001). However, we found no association between illusion strength and either visual (r=.02, p=.808) or kinaesthetic (r=.11, p=.206) imagery, revealing how the illusion is more closely related to low-level sensory mechanisms constrained by our physicality rather than higher-level perceptual simulation processes.

Postural demands influence head contributions during visual tracking

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Humans use vision to perform various everyday tasks. From looking for the next foothold during walking to visually tracking a flying bird, gaze shifts can be performed either by isolated eye movements or by combined eye-head movements. Even when isolated eye movements allow gaze shifts of the desired amplitude, humans still engage their heads. Such head movements can provide additional sensory signals that can be integrated with retinal input and improve gaze estimates. However, head movements can also create mechanical torques that could disturb balance and suppress vestibular processing, both of which could challenge the retention of upright stance. We are here interested in characterizing how humans coordinate their head and eye movement systems when visually tracking a moving object under conditions of different postural demands. Participants tracked a visual stimulus that moved along a sinusoidal horizontal path of different amplitudes (visual angle of 15^o, 42^o, 95^o) and we expected larger head rotations with larger path amplitudes. To examine how postural demands influence the head's engagement, participants performed the task while sitting, standing, and standing on a piece of foam. As expected, participants rotated their heads more as a function of the path's amplitude. They also moved their head more when standing in more demanding postures, and this was also reflected in a positive correlation between the amplitude of head motion and the center of pressure path. More demanding postures also induced a greater head and trunk coupling. Thus, engaging the head for gaze shifts not only allows larger gaze excursions but also reflects the postural demands of the task at hand, suggesting that humans trade off postural stability to allow greater head engagement facilitating the execution of the visual task.
Acknowledgements: This work is supported by the German Research Foundation under grant agreement VO 2542/1-1.

Symposium 4 - Congenital achromatopsia as a model testing vision development and plasticity

Achromatopsia - limits of visual cortex plasticity in the absence of functional cones

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Background. Complete achromatopsia is a rare inherited disorder where retinal cone photoreceptors are congenitally non-functional and vision is exclusively driven by rod-input. As a consequence, due to the absence of rods in the fovea, the visual cortex does not receive visual input to its sizable foveal representation. This life-long deprivation of the visual cortex from foveal visual input, prompts the fundamental question, whether the cortical representation of the central visual field in achromatopsia is remapped to take up processing of paracentral inputs. Such remapping of the visual cortex would be of great relevance for potential clinical interventions, as it might interfere e.g., with gene therapeutic treatments currently tested for restoring cone function in human achromatopsia. Methods: In a multi-center 3 T fMRI study, we addressed this question by comparing a cohort of individuals with autosomal recessive achromatopsia with confirmed CNGA3 or CNGB3 mutations (n=17) with controls (n=19). Two independent mapping approaches were applied to separate data sets, i.e., conventional phase-encoded eccentricity and population receptive field (pRF)-mapping. Results: Both approaches produced the same result in the comparison of achromatopsia vs controls: Remapping of the representation of the central visual field in the primary visual cortex was not apparent at the group level. Conclusion: Remapping of the primary visual cortex does not appear to be

a general group feature of achromatopsia. It is concluded that plasticity of the human primary visual cortex is less pronounced than previously assumed.
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Structural differences in adult visual cortex following development without functional cone input

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Congenital achromatopsia (ACHM) is a rare inherited visual condition that renders retinal cone photoreceptors non-functional from birth. As the central fovea is occupied solely by cones, affected individuals have a small central blind spot and an absence of inputs to corresponding representations in visual cortex. In addition, chromatic signals to the brain are absent due to the role of cones in colour perception. Although recent clinical trials using gene replacement therapy show promise in restoring cone function in the eye, success may depend on maintaining normal structure and function in downstream visual pathways. To assess whether ACHM leads to developmental structural differences in the brain, we collected T1-weighted MRI scans in 15 individuals with ACHM and 42 controls. Surface-based morphometry was used to measure cortical thickness, surface area and volume in atlas-defined visual areas throughout the occipital lobes. Reduced grey matter volume in V1, V2, V3, and V4 was found in ACHM compared to controls, driven by reduced cortical surface area in these areas. Surface area was also significantly reduced in areas TO1 and LO1. Cortical thickness was comparable between ACHM and controls when averaged across entire visual areas. However, the region within V1 receiving the most central inputs (0-4deg) was significantly thicker in ACHM vs. controls. These changes were analogous to reports of increased thickness throughout V1 in congenitally blind individuals, suggesting similar developmental processes irrespective of the underlying cause of vision loss. Changes in early visual areas with large central representations (V1/V2/V3) suggests the lack of foveal input to the visual cortex was a major driving factor in structural differences in ACHM. However, the significant reduction in ventral area V4 coupled with no difference in dorsal areas V3a/V3b suggest that deprivation of chromatic signals to visual cortex in ACHM may also contribute to changes in cortical morphology.
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Approaches and challenges to measuring cone-specific responses in clinical populations

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The human retina contains five photoreceptor classes: the L, M, and S-cones, rods, and the melanopsin-containing retinal ganglion cells. The spectral sensitivities of these cells overlap extensively, and are further influenced by structural variation within the eye across eccentricity, and by variation between individuals in genetics and pre-receptoral filtering. Many experiments seek to selectively target these photoreceptor classes alone and in combination, using manipulations of background light level, spatial and temporal modulation frequency, and spectral content. These approaches have been used in the study of inherited retinal disease generally, and in congenital achromatopsia in particular, to both characterize baseline deficits and test for the effects of treatment. I will describe efforts in my lab and as pursued by others to measure physiologic and neural responses that are specific to different photoreceptor classes. In particular, I will describe the design and application of "silent substitution" stimuli that attempt to isolate stimulation to particular photoreceptors. Using these techniques, we have measured the selective contribution of cone and melanopsin signals in perception, pupil response, and fMRI activity, and have done so in people with normal trichromatic vision, in dichromats (deuteranopes and normal dogs), and in retinal disease. While powerful, however, there are inevitable imperfections in the targeting provided by this approach. I will provide a rogues' gallery of failures of silent substitution, including due to device imprecision, incomplete rod saturation, spectral filtering properties of the pre-receptoral structures of the eye, and the effect of transverse chromatic aberration. Finally, I will discuss techniques that may be used to measure and mitigate these inevitable imperfections of a powerful experimental approach.
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Cone-mediated visual function after gene therapy in achromatopsia

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Achromatopsia is a congenital condition that causes cone photoreceptor dysfunction, relegating vision to rod photoreceptors. This results in low acuity, complete colour blindness, photophobia, nystagmus, and lack of light sensitivity in the foveal rod-free retina. Gene therapies offer promise for treating achromatopsia, with successful cone rescue in animals showing greater functional benefits for earlier treatment. This age effect highlights the importance of considering critical periods for cone rescue. In research alongside pioneering gene therapy trials in 6 to 16-year-old children with achromatopsia, we investigated the potential for gene therapy to reactivate dormant cone-mediated pathways in young patients. We first characterised cortical adaptations to life-long rod only vision, to identify potential neuroplasticity hurdles for therapy. We found that in children with achromatopsia, the mapping of retinal signals onto cortical input regions (V1) stays remarkably stable compared to the normal sighted rod system, concordant with recent findings in adults by others. However, we additionally found evidence for a new type of plasticity, manifested as reorganised read-out of cortical inputs (V1) by higher-order cortex regions (V3), in a pattern that could compensate for the lower resolution of a rod-only system and its lack of high-density foveal input. These dynamics could reflect a broader principle of optimising available input while keeping sensory-to-cortex connections stable. To evaluate the effect of cone restorative gene therapy on this system, we selectively stimulated the cone photoreceptors in the eye, and measured signal transmission to visual cortex. We found new cone-mediated retinotopic maps emerge

after gene therapy in a subset of patients. These brain changes were paired with significant improvements in cone vision, selective to the treated eye, providing strong converging evidence for novel cone function. The functional characteristics provide novel insights into which cone signals are rescued and how these are integrated into the brain's existing functions.
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Following gene augmentation therapy: cone-mediated vision and its limits after a lifetime of rod monochromacy

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Complete CNGA/B3 achromatopsia is a congenital hereditary disease characterized by cone dysfunction, resulting in exclusively rod-driven vision even under light conditions. Consequently, affected individuals exhibit lifelong symptoms including low visual acuity and complete color blindness. At our center, recent treatment approaches have focused on gene augmentation therapy, administered unilaterally to three adult patients and one child, with the aim of potentially reactivating dormant cones. A key question remains: can the adult brain adapt to process the new cone input? Our investigations have covered various aspects of visual function in these patients, employing both behavioral assessments and imaging techniques. Using MRI, we demonstrated that prior to treatment, patients exhibited abnormally increased population receptive field (pRF) sizes within early visual areas, along with diminished fiber integrity along occipito-callosal pathways. Following treatment, improvements in both parameters were observed, although they did not reach levels seen in normally sighted populations. Behaviorally, patients reported subtle visual alterations after treatment, with no or slight improvements in visual acuity. Notably, specialized color perception tests revealed faint red perception in the treated eye. Additionally, assessments of temporal vision indicated increased sensitivity to higher frequencies in the treated eye compared to the untreated eye, albeit not to the extent found under unharmed cone processing. Encouragingly, greater behavioral improvements were observed in the child than in adults. To summarize, results from our treated achromatopsia cohort mirror observations from newly sighted individuals. The modest improvements seen upon introduction of new visual signals in adulthood are thought to reflect the closure of visual critical periods during childhood. Our results underscore persistent visual challenges following vision restoration, even in cases where vision developed under unaffected rod input. Importantly, our study highlights the utility of investigating this rare cohort in exposing critical periods for specific visual attributes such as temporal and color perception.
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Spotlight in Vision Lecture

Modelling Vision in the Face of Large Language Models

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Artificial neural networks (ANNs) have emerged as the central tool responsible for recent AI breakthroughs. As the foundations of ANNs lie in the connectionist movement, cognitive computational neuroscience was quick to recognise their promise to act as "Goldilocks" models of brain function, striking the balance between biological realism and algorithmic clarity. Indeed, ANNs can be grounded in sensory data, can be trained to perform complex tasks in a distributed fashion, are fully accessible to the experimenter, and can be mapped to brain function across various levels of explanation. Especially in vision, this has led to a fruitful research cycle in which biological aspects are integrated into network design, and the corresponding networks are then tested for their ability to predict neural and behavioural data. What emerged is a cohesive large-scale research programme, termed neuroconnectionism, which is centred around ANNs as a computational language for expressing falsifiable theories about brain computation. In this talk, I will describe a recent case study of neuroconnectionism in which we asked whether large language models (LLMs), i.e. ANNs trained on large text corpora, can provide a good representational format for modelling human visual responses to natural scenes. While perhaps counterintuitive to model visual processing via models trained purely on language, we demonstrate that visual representations in the human brain are indeed aligned with LLM representations. By running tightly controlled model comparisons, we demonstrate that recurrent neural networks, trained to map from pixels to semantic LLM embedding, provide the current best account of a large-scale, 7T fMRI dataset (NSD), outperforming other supervised as well as unsupervised ANN models. These findings point towards the view that vision may not be optimised for visual categorisation alone, but instead maps from retinal input into a high-dimensional semantic format that can be captured by contextual learning in language.

Poster Session 4

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Depth reversals in Patrick Hughes' Reverspectives: a flippin' problem

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Background: Patrick Hughes' Reverspectives have provided us a valuable tool for investigating the relative contributions of binocular disparities, perspective and motion parallax in 3-D vision. Approaching a Reverspective from a distance, perception is dominated by the receding perspective information on the flanks of the truncated pyramids until (at ~100 cm) the percept "flips" (Richard Gregory) to that of the actual protruding structure. Aims: The present study was designed to investigate the factors that affect the flipping distance: angular size, disparities, viewing distance and presence/absence of motion parallax. Methods: Virtual versions of Patrick Hughes' Reverspectives were displayed at two different distances (130cm & 318cm) and two different angular sizes (49˚x18˚ & 24.5˚x9˚). Disparities were varied from crossed (protruding structure), to flat, to uncrossed (receding structure). The amplitude of motion parallax was varied to simulate viewing from either a distant or a close 3-D structure. In separate trials, observers viewed either a stationary virtual Reverspective or a dynamic virtual Reverspective using the motion parallax created by the observer's side-to-side head movements. Results: Increasing the size of the crossed disparities increased the likelihood of perceiving the 3-D structures as protruding but only in the stationary viewing condition. With motion parallax provided by head movements, observers overwhelmingly perceived the "reversed" depth structure that was consistent with the perspective information provided by the "flanks" of the virtual Reverspective. Angular size and distance mattered but only because the disparities of a scaled-down Reverspective (same depth-to-width ratio) decreased in proportion to size. Conclusions: flipping distance is primarily determined by the relative strength of the perspective information and the magnitude of the disparities (rather than distance per se). More importantly, the results reveal that there is close synergy between perspective and motion parallax (motion perspective) that is capable of overruling the binocular disparities.

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Investigation of the Interplay Between Natural and Learned Priors in Autistic and Non-Autistic Individuals

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Background: Autism is a neurodevelopmental condition that affects various cognitive and behavioral functions, including social interaction, communication, and sensory processing. It has recently been suggested that sensory processing in autistic individuals depends less on perceptual prior knowledge and expectations, and more on immediate sensory information. However, prior knowledge can be classified into pre-existing (natural) priors – expectations established before receiving task-relevant information – and learned priors – expectations induced by a task. Nevertheless, the interplay between natural and learned priors, that can inform how perception is adjusted to incorporate new learned information, has not been thoroughly studied, especially in the context of perception in autism. Objectives: We aimed to explore whether and how natural and experimental priors interact in non-autistic and autistic individuals. Method: Autistic (n=15) and non-autistic (n=15) individuals performed a 2IFC orientation discrimination task. Participants were sequentially presented with two Gabors (Spatial frequency = 3°) stimuli at the center of the screen and were asked to report the Gabor with the most clockwise orientation. We tested performance around threshold level over a range of orientations (25°-65°). Stimuli were drawn from a uniform distribution. We assessed priors' effect by measuring performance bias. To assess natural priors, we measured bias toward the cardinal orientations. To assess learned priors, we tested bias toward the mean of the presented range of orientations (45°). Results and conclusions: The autistic and non-autistic groups showed a bias toward the cardinal orientations, except for orientations around the mean, where they showed a bias toward the mean of the overall presented orientations. The interaction between the two types of priors showed a stronger bias of perceptual judgments by a natural priors in both groups. These findings show that contrary to prevailing views, autistic individuals integrate either natural or learned priors in a manner similar to non-autistic individuals.

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Journey towards restoration: Does statistical stability in a train of natural scenes benefit cognition?

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There is empirical evidence that exposure to natural scenes, even when presented as images on a screen, can provide benefits on certain cognitive tasks. Although several theoretical frameworks have been proposed for understanding this phenomenon, few have directly attempted to investigate the visual mechanisms underlying such benefits. A perceptual fluency account is one candidate, which would explain benefits as being derived from nature because of the ease with which those images are processed by the brain. Corbett and Melcher showed that the visual statistical stability of the array of search stimuli supports efficient visual search, even when the statistic is not relevant to the task at hand (i.e. stability in mean size supports search for orientation singletons). We investigated whether this effect of statistical stability would extend to images, as a potential mechanism underlying the cognitive benefits of viewing natural scenes. We presented observers with trains of images from the Salford Nature Environments Database, in blocks during which the presentation order of images was controlled in terms of the slope of the Fourier power spectrum ("spectral-slope") – an image statistic associated with naturalness and aesthetic preference. In stable blocks, images were presented in order of their spectral slope (i.e. ascending/descending) such that the change in that image statistic from one image to the next was minimal. In unstable blocks, the image order was random with respect to spectral slope. Interleaved within each block of 288 images were 96 trials of a flanker task measuring executive attention, which has previously been shown to be affected by exposure to nature. Preliminary analysis suggests that, contrary to our hypothesis, the presence of statistical stability, in terms of spectral slope, does not support enhancement in executive attention. We discuss the possible role of image statistics in understanding the mechanisms of attention restoration from nature.

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An adaptable spatial metric is sensitive to adaptor orientation

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Adapting to a dynamic texture pattern comprising drifting Gabors or flickering dots can induce compression in the perceived separation of subsequently presented stimuli. Here we report an unexpected directional dependency in this compression aftereffect when adapting to dynamic cosine wave gratings. Participants adapted to a grating which oscillated sinusoidally in spatial frequency (0.5 – 5.5 cycles per degree) at a frequency of 1 Hz. This produced a concertina effect, with motion directed away from a fixed central axis. The adaptor was presented at 30% contrast in a square window (6 x 6 degrees of visual angle) centred 6 degrees from fixation on a uniform gray background. After adaptation (30s + 5s top-up), two pairs of dots were simultaneously presented in adapted and non-adapted areas located either side of fixation. Participants reported which pair had the greater separation. The separation of one pair of dots was kept constant while the other was varied to estimate the point of subjective equality (PSE), which provided a measure of the compression aftereffect. Apparent compression was measured for combinations of both vertically and horizontally oriented grating adaptors and stimulus dot pairs. The dots were either aligned with the grating bars, or perpendicular to them and thus aligned with the direction of motion during the spatial frequency oscillation. Greater shifts in PSE, indicating a stronger compression aftereffect, were observed when dots were aligned with the grating for both horizonal and vertically oriented grating adaptors. Thus, paradoxically, strongest spatial compression was induced perpendicular to the direction of grating motion (i.e. along the length of the bars), despite no local change in luminance in the adaptor at, or between, the specific locations at which dots were presented. The orientation dependence of the adaptation effect indicates the likely involvement of cortical mechanisms in determining the metric of visual space.
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Numerosity Is Driven By Intermediate Visual Representations

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Number sense, the ability to rapidly estimate the approximate number of objects in a visual scene, is a universal human ability that extends even to pre-verbal children and many other animals. Recent computational work has suggested that number sense could emerge in visual systems from observing changes in a scene as they arise from object quantity manipulation, without any access to explicit numerical labels. Here, we extend this framework using photorealistic multi-object stimuli, and explore the role of different pre-trained object-classification convolutional neural networks for feature extraction. Iterating through the layers of various object-classification networks we observed that using intermediate - rather than early or late - feature representations maximized both performance on the manipulation recognition task and the emergence of explicit numerosity information at later stages of the model. This pattern of results persisted across a wide variety of training regimes, network architectures, and even for stimuli containing higher numbers of objects than those encountered during training. However, no such 'midway peak' was present in the intermediate representations of randomly initialized models, or those optimized to perform the manipulation recognition task rather than object-classification. Taken together, our work demonstrates that the intermediate representations learned by visual object-classification systems drive the emergence of quantity information in a context of object manipulation, even without the presence of explicit numerical labels. These computational results suggest that the intermediate visual features computed in the brain could be involved in the mechanisms underlying the phenomenon of number sense.

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Comparable colour constancy for average colour and single colour percepts.

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Colour constancy refers to the visual system's ability to correctly estimate surface colours under varying illumination. Most previous studies have employed stimulus surfaces with uniform chromaticity or limited chromatic variation. Can colour constancy operate equally well—or better—for surfaces with significant chromatic variation? We characterised percepts of average colour across an illumination change for uniform and polychromatic surfaces. We used realistically rendered images of 3D scenes that were divided horizontally to yellowish and bluish illumination regions. Four 3.3° irregular "blob" objects were embedded in the scene in a two-by-two configuration (separated by 2.2° vertically and 3.6° horizontally), with two objects in each illumination region. The object surfaces were either uniform or polychromatic, and background surface was either uniform grey or made of differently coloured squares. On each trial, three objects had the same (average) surface colour. The fourth surface colour (target) varied from yellowish to bluish from trial to trial. The stimulus was shown for up to 2000 ms, and observers (N = 20) responded which of the four objects had a different (average) surface colour. Correctly choosing the illumination region containing the target reflects the ability to discriminate colour. Given correct choice of region, correctly choosing the target object reflects colour constancy relative to discriminability. Thresholds and biases for both choices were estimated from psychometric function fits to the proportion of correct responses. Based on within-subject contrast analysis in a linear mixed model, discriminability was poorer for polychromatic than uniform objects ($t(139) = -11.76$, $p < .001$), but colour constancy was the same for both. Compared to a uniform grey background, a multi-coloured background made discriminability slightly poorer ($t(139) = -2.34$, $p = .021$), but had no effect on colour constancy. We conclude that colour constancy operates equally well for average and single colour estimates.
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Facial expression recognition with regard to faces behind observers

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In previous studies, facial expression recognition ability has typically been tested while a person views a face from the front, such as when an observer sits down and views a facial stimulus on a monitor. However, it remains unclear whether the spatial relationship between the observer and the observed face affects the extent to which facial expressions can be perceived by the observer. For example, when another person's face is positioned behind the observer, such as when the observer is being chased, the observer may perceive the person to be a threat and engage in survival strategies. Thus, we investigated whether facial expression recognition ability changes when faces are positioned behind the observer in a virtual environment. We generated facial expressions that varied between neutral and angry using FaceGen. A face stimulus appeared either in front of or 180 degrees behind the participants, requiring them to turn to the left or right to view the stimulus. The participants indicated whether the face appeared to be neutral or angry. The results showed that the faces were perceived to have stronger expressions when they were positioned behind rather than in front of the participant. Additionally, when we changed the target expression to happy, the faces positioned behind the participant were perceived as happier than the faces positioned in front of the participant. In subsequent experiments, we introduced a hand-mirror condition in which the observers were allowed to use a hand mirror to view the faces behind them without body rotation. The results revealed strong perceptions of the angry faces positioned behind the observer; however, body rotation was required in the context of the happy faces. We suggest that this enhancement of facial expression recognition relies on emotional valence to ensure the efficient detection of threats in the environment around observers.
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Temporal dynamics of representations shared between visual perception and imagery

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Visual imagery is the ability to conjure up perception-like percepts in the mind's eye in the absence of an external physical stimulus. This suggests that imagery and perception share common representations, but the dynamics with which shared representations emerge remain incompletely understood. Here we determined the temporal dynamics and spectral signature with which neural representations shared between imagery and perception emerge. We used electroencephalography (EEG) to resolve neural representations while human participants (N=41) looked at or imagined 12 different stimuli (in the categories faces, houses, and tools). We used representational similarity analysis (RSA) to characterise and relate neural representations evoked in imagery and perception. We made two key findings. First, in a time-resolved analysis we found that imagery and perception share representations across broad time windows: starting from ca. 80 ms after stimulus onset in perception, and between 180-1400 ms relative to cue onset in imagery. Second, in a time-frequency resolved analysis we found that imagery and perception share representations predominantly in the alpha and lower beta band. Together our results reveal the temporal dynamics and spectral characteristics of neural representations shared between imagery and perception. Both aspects are consistent with a set of previous studies, and add further evidence from different methodology and experimental setup to our growing knowledge of the neural basis of imagery and perception.

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Exploring emotional dimensions and colorimetric structures of abstract paintings through psychophysical scale

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We conducted an experiment with 75 Brazilian participants (mean age = 31; SD = 1.1; 29 women), in which they were asked to rank ten abstract paintings based on six emotional descriptors: tense, calm, exciting, boring, enthusiastic, and depressive. These descriptors were selected based on the circumplex model of affect, wherein each emotion can be understood as a linear combination of two distinct systems. We employed a psychophysical methodology to analyze the ranking data using the Law of Comparative Judgment. This involved calculating the statistical distances between all paintings for each emotional descriptor to establish an interval scale. Correlations among the six emotional scales were assessed using Pearson's coefficient, revealing negative correlations for tense-calm, enthusiastic-depressive, and exciting-boring (<-0.85, $p<0.05$), and a positive correlation for exciting-enthusiastic (0.90, $p<0.05$). Furthermore, we analyzed the color gamut of each painting in CIE Lab space, deriving values for three colorimetric dimensions: saturation, color proportion, and hue. We conducted a one-way ANOVA to investigate statistical relationships between the colorimetric structure of the paintings and the emotional scales. Our findings demonstrated a statistically significant difference between saturation and the depressive scale ($F=0.68$, $p<0.05$). Our results suggest that abstract paintings can be mentally categorized into emotional continua, with these continua displaying a logical interval organization within opposing emotional dimensions. The lack of a relationship between colorimetric structure and the emotional intensity of the paintings suggests that color may not significantly influence emotional judgment, while other elements and attributes within visual perception may play a more significant role and require further investigation. These findings underscore the complexity of emotional judgment involved in visual perception and highlight the uniqueness of the aesthetic experience. By applying this methodology to a sample of the Brazilian population, we can gain insights into how specific emotions influence visual perception in artistic appreciation.

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Image statistics and the visibility of distortions in things and stuff

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The content of photographic images can be differentiated along qualitative dimensions, such as man-made versus natural, and things (predominantly isolated objects or scenes) versus stuff (predominantly material properties or texture). Though no precise definition of these dimensions exists, they have been previously demonstrated to influence scene categorization and sensitivity to local structural perturbations. Here, we examine the relationship between these qualitative dimensions and a set of simple image statistics: spatial coherence (variation in edge density such that low variation means high coherence), contrast energy (average local contrast in spatial frequency bands), and the intercept and slope of the Fourier amplitude spectrum over frequency. We further measure human sensitivity to Eidolon-like distortions in a set of images sampled over a range of these dimensions (from the THINGS and STUFF databases), in order to provide a data-driven means to compare models of visual sensitivity. Participants discriminated original and Eidolon-distorted images presented peripherally in a three-alternative temporal oddity task, for different distortion intensities (reach) and spatial frequencies (grain). We found that Eidolon-like distortions were easier to detect (lower reach thresholds) at all grain values in more scene-like images compared to texture-like images. Participants were also less sensitive to higher grain distortions, i.e. distortions of lower spatial frequency, in a pattern reminiscent of the contrast sensitivity falloff with lower spatial frequency. We characterize the relationship between participants' sensitivity and changes in the above image statistics on an image-level to explain sensitivity variations not accounted for by the CSF. We find that spatial coherence and contrast energy provide a useful low-dimensional characterization of distortion sensitivity over images ranging from things to stuff.
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Comparison of left-visual-field bias in autistic individuals in 3D VR environments versus a 2D task

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Autism Spectrum Disorder (ASD) is a neurodevelopmental condition defined by DSM-III criteria in 1980, with core symptoms affecting social and communication skills, self-regulation behaviour and sensory perception. Due to the high variability of ASD, assessment can be highly subjective and affected by environmental and social biases. Recent research has taken advantage of technological advancements such as eye-tracking and a virtual-reality immersive HMDs to ensure more objective, accessible and personalised data collection. The objective of this study was to investigate and describe the visual behaviour of a group of ASD individuals (age 12 to 17 years old), comparing their performance in a 3D environment relative to that of another group previously tested in a 2D environment. The protocol consisted of a brief series of standard visual tasks assessing face perception (using 3D human and animal avatars), object recognition (using 3D models of objects and toys), joint attention (comparing side-by-side presentations of two- vs three-dimensional objects placed in the left and right fields of view respectively) and free-scanning of social scenes. Eye-tracking data such as gaze movements, saccade and fixation behaviour were collected in a fully immersive virtual environment to study the impact of the depth information element available in the current replication, relative to the previous 2D version of the same protocol. A systematic left-field-of-view bias was compared between the ASD populations tested under the two environments as well as in relation to an age and gender-matched neurotypical control group. These findings aim to increase our understanding of how depth perception is processed in autism, a field yet largely unexplored, as well as to explore the usability of virtual reality head-mounted displays with incorporated eye tracking for the assessment of ASD individuals.

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Looking down: Downcast gaze influences the believability of happiness and sadness in computer-generated faces

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Computer-generated (CG) people are increasingly common in society. To be feasible in settings such as telehealth or customer service, CG people need to communicate effectively with their human counterparts—which includes expressing emotions in a way that humans find believable, interpreted as seeming to have come from a felt emotion. The present study aimed to test how eye-gaze direction can be used to optimise the believability of CG facial expressions. Our starting point was that, for human faces, direct and downcast eye-gaze are theorized to contribute to the communication of happiness and sadness respectively. We therefore hypothesised that direct-gazing happy CG faces and downward-gazing sad CG faces would be more believable than those gazing elsewhere. Happy and sad expressions were each animated on eight CG people in Unreal Engine. These expressions were based on FACS configurations previously reported in human faces. Six increasingly downcast angles of gaze were presented across trials while participants (N = 75) judged the believability of each expression. Happiness was found most believable with direct gaze, with believability progressively decreasing as gaze turned downcast. Sadness, however, steadily increased in perceived believability as gaze aversions became more downcast. These findings demonstrate that eye-gaze direction influences the perceived believability of expressions of happiness and sadness in CG faces, as per our hypotheses. Practically, our result can inform the development of CG humans with increasingly effective communicative abilities. More broadly, our findings highlight the importance of conceptualising eye-gaze as a component of facial expression perception, which has also been largely overlooked in studies of human expressions, which mostly use only direct-gazing stimuli.
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Visual factors influence perceived time of eye movement but not visuo-motor temporal recalibration

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We previously demonstrated that systematic sensory delays associated with saccadic eye movements are rapidly learned—a perceptual realigment of asynchronous signals termed temporal recalibration. However, judging saccade timing often involves high levels of uncertainty. If observers rely on visual factors to discern saccade timing, then an increase in visual information might enhance an observer's certainty of when exactly their eyes moved and thereby moderate temporal recalibration. To examine the impact of visual factors on subjective timing and temporal recalibration, we manipulated the availability of target and background information in a 2-by-2 design. Observers made horizontal saccades that triggered a brief, high-contrast Gaussian flash presented either during or after the movement. To induce temporal recalibration, 60% of trials presented flashes with consistent delays of either 20 or 80 ms after movement onset, applied in separate blocks. In randomly interleaved report trials (40%), flash delays were systematically varied via an adaptive staircase procedure, with observers reporting temporal order of flash and saccade offset. Within each session, four visual conditions were presented in separate blocks. They featured either repetitive noise backgrounds (bandpass-filtered to low spatial frequencies) or a uniformly grey background. The saccade target (a 2 dva black circle) was presented either pre-saccadically (for 50 ms) or continuously until the end of the trial. Across all visual conditions, saccade offset was perceived later in the delay condition, replicating temporal recalibration. Moreover, post-saccadic availability of the saccade target increased reliability of reports in both baseline and recalibrated states. Thus, while visual factors play a role in eye movement timing, recalibration was robust to them. This robustness suggests that temporal recalibration is a fundamental mechanism that responds to mismatches between saccades and their visual consequences. Visual cues like saccade-induced smear could therefore contribute to calibration of causal inferences about saccades' visual consequences in natural vision.
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Asymmetric effect of Action-Effect uncertainty and feature uncertainty on action effect binding

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A stimulus perceived as the consequence of one's action is processed differently compared to externally triggered ones. This difference is perceptually characterized by intentional binding, where the perceived temporal proximity between action and effect forms an action-effect event. Previously, it was shown that a feature singleton captured attention when preceded by an action even when its location was variable across trials. Similarly, capture was not observed when the location of the singleton was fixed across trials. However in both of these experiments action and no-action were manipulated across different experimental blocks. We report three experiments with various levels of uncertainty attached to the feature singleton within the trial structure. We used an irrelevant singleton paradigm where participants were required to respond to the identity of a target in the visual display (2 or 5 among other numbers). In half the trials participants were required to press a key (as indicated by '+' or 'o' at the fixation) to initiate display onset while in the other half, the display onset was automatic. Thus action and no-action conditions were randomized across trials rather than in separate blocks. In the first experiment, the location of the feature singleton was random. In the second experiment, the location of the feature singleton was constant across trials and was invariable across both the action and the no-action conditions. In the third experiment, the action and no-action conditions were assigned their own unique feature singleton location. The data suggests that the feature singleton captures attention only in the third experiment, not in the first or second. That is, randomizing action and no-action across experiments eliminated capture observed previously. However, having distinct stimulus features associated with action and no-action re-establishes capture. The study suggests an asymmetric relation between uncertainty with respect to action-effect contingency and feature level uncertainty.

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Pre-attentive computation of density-defined motion

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Spatial modulations of dot density and dot contrast are easier to detect when they are combined in phase. Antiphase combinations, in which high densities coincide with low contrasts, are more difficult, but they are not impossible to detect. These previous findings imply a minimum of two mechanisms having differential sensitivities to the two types of modulation. To determine whether either of these mechanisms relies upon attentionally modulated input, we measured (81%-correct) threshold modulation amplitudes for discriminating between leftward and rightward translating texture modulations at 0.94, 1.88, 3.75, and 5.00 Hz. As expected, thresholds increased with temporal frequency. When density and contrast modulations were combined in equal multiples of their thresholds in isolation, again we found low threshold multiples for in-phase combinations and high threshold multiples for antiphase combinations. However, there was no systematic effect of temporal frequency on these multiples. To decrease thresholds, allowing measurements at higher temporal frequencies, all dots were given negative Weber contrasts, and the texture modulations became angular, requiring discrimination between clockwise and anti-clockwise rotations. Threshold multiples for antiphase combinations were no greater at 7.50 Hz than they had been at 0.94 Hz. Texture modulations at threshold for direction discrimination were then superimposed on static modulations having twice the threshold amplitude. These static pedestals can foil attentionally modulated feature-tracking decision strategies. Indeed, superimposition of static pedestals did impair some observers' direction discriminations with some of the textures at lower temporal frequencies; but this was true for all textures, not just the antiphase combinations. Consequently, these results suggest that while attention may modulate the salience of textures based on the density and/or contrast of its constituent parts, attentional modulation is not necessary for perception of a density modulation, even when the salience of that density modulation is minimized by antiphase combination with a contrast modulation.

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About cross-modal commutativity in magnitude production

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Can we compare the loudness of a tone to the brightness of a light? The answer is yes. We are intuitively capable of these cross-modal comparisons. Psychophysical researchers such as Stevens have long assumed that these cross-modal comparisons are mediated by a single scale of subjective intensity. Luce developed a psychophysical theory for physical intensity making Stevens' assumptions towards an underlying scale of perceived intensity explicit and formulating empirically testable conditions for it. They identified cross-modal commutativity as a property through which the theory can be tested. We investigated this property in a cross-modal magnitude production task between auditory and visual stimuli, concerning their loudness and brightness respectively. Participants were presented with the two stimuli and instructed to, for example "make the tone 3 times as loud [as the visual stimuli appears bright]". This was partly a replication of a paper in which the original authors concluded that cross-modal commutativity holds whereas we find inconclusive evidence in a Bayesian analysis. Additionally, in a theoretical analysis, we find evidence that role-independence of the internal references used in magnitude production is violated. In an expansion of Luce's theory, Heller concluded that cross- modal commutativity holds if and only if the internal references are role-independent, meaning they are not dependent on whether the reference pertains to the standard or the variable stimulus. This means, if role-independence of the references is violated, the assumed intensity scale can hold even if cross-modal commutativity doesn't. Evidence towards this conclusion and its implications will be discussed.

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Population coding for figure-ground texture segregation in macaque V1 and V4

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Object recognition often involves the brain segregating objects from their surroundings. Neurophysiological studies of figure-ground texture segregation have yielded inconsistent results, particularly on whether V1 neurons can perform figure-ground texture segregation (e.g., Lamme, 1995) or just detect texture borders (Rossi, et al., 2001). To address this issue, we utilized two-photon calcium imaging to simultaneously record the responses of large samples of V1 (n=1983) and V4 (n=2820) orientation-tuned neurons to figure-ground texture stimuli in parafoveal FOVs of six awake, fixating macaques. The figure-ground textures consisted of a 4°?4° figure embedded in a 32°?32° ground, consistent with those used by Lamme (1995). The figure was formed by iso-oriented lines at one of four orientations (0°,45°,90°, and 135°), and the ground was comprised of lines orthogonal to the figure lines. The stimulus was positioned relative to the population receptive field (pRF) of a FOV, such that the figure, figure-ground border, and ground fell on the pRF, respectively. The average response changes indicated that V1 neurons mainly detect texture borders, while V4 neurons are involved in figure-ground segregation. However, population analysis (SVM decoding of PCA-transformed neuronal responses) revealed that V1 neurons not only detect figure-ground borders, but also contribute to figure-ground texture segregation, although requiring substantially more principal components than V4 neurons to reach a 75% accuracy. Individually, V1/V4 neurons showing larger (negative/positive) figure-ground response differences contribute more to figure-ground segregation. But for V1 neurons, the contribution becomes significant only when many principal components are considered. We conclude that V1 neurons participate in figure-ground segregation primarily by defining the figure borders, and the poorly structured figure-ground information they carry can be further utilized by V4 neurons to accomplish figure-ground segregation. These results help reconcile prior inconsistencies on the roles of V1 in figure-ground texture segregation from a population perspective.
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Brain regions representing numerosity across the senses and presentation formats

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Numerosity can be extracted in a plethora of situations: the number of pens on a table, of knocks on the door, or of times a hammer hit a nail. How does the brain compute the same numerosity (e.g. three) across different modalities (e.g. auditory, visual) or different formats (symbolic or non-symbolic; simultaneous or sequential)? Whether and where the brain represents numerosity in an abstract fashion or separately across formats and modalities remains debated. We used Functional Magnetic Resonance Imaging (fMRI) to characterize the brain activity of participants processing numerical information (range 2-5) across modalities (auditory, visual) and formats (sequential, simultaneous; symbolic, non-symbolic), to collect a comprehensive mapping of numerical representation across multiple dimensions. Multivariate pattern decoding analyses (MVPA) first show that multiple brain regions within the dorsal stream, from early stages of visual processing (area V3b) to the lateral intraparietal area (LIP), encode non-symbolic numerosity across formats and modalities. Cross-modal decoding analyses show that only the representations of auditory and visual sequential numerosity are shared in V3, parietal and frontal regions, mainly in the right hemisphere. The results suggest that a general coding of numerosity across sensory modalities depends on the shared format of presentation (i.e., sequential). Overall, our study demonstrates that a series of dorsal brain regions encode absolute non-symbolic numerosity across vision and audition and in different formats, but that a shared representation across sensory modalities only emerges when numerosities share a similar presentation format.

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Location-specific improvements in spatial attention induced by training on a crowding task

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Visual crowding, the difficulty in recognizing objects in the periphery amid distractors, can be at least partially mitigated through perceptual learning. Enhanced target recognition has been shown to transfer to untrained locations of the visual field. However, it is not clear to what extent such improvements in trained and untrained locations can be attributed to improvements in spatial attention following perceptual learning. In this study, participants underwent a Landolt-C gap detection training daily over 4 days in the left and right quadrants at 10° eccentricity in either the upper (N = 12) or the lower (N = 12) visual hemifield. A 2-down, 1-up adaptive procedure adjusted the critical spatial distance of two ring-shaped flanker distractors positioned radially and tangentially to the Landolt-C with respect to central fixation. All trained participants, as well as an untrained control group (N = 12), underwent spatial attention and crowding task testing at the same positions at 10° eccentricity before and after training in both hemifields. In the crowding task, both training groups showed significant ($p < .05$) improvements in their trained hemifield, as well as significant transfer of these improvements to the untrained hemifield. In the spatial attention task, both training groups displayed significant improvements only in the hemifield that had been trained in the crowding task, indicating no transfer of spatial-attention improvements between upper and lower hemifield. The results indicate that perceptual training in a crowding task leads to location-specific improvements in spatial attention. However, these improvements occurred independently of training-induced improvements in the crowding task.
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Direction congruency in the Motion-Bridging-Effect: The transfer of unconscious direction information from a spinning ring

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The “Motion Bridging Effect” is a motion illusion in which a rapidly rotating ring of dots induces a rotation percept in a previously or subsequently presented stationary ring of dots. The illusory rotation's direction usually matches the rotating ring's direction, although this direction is undetectable when only the rotating ‘inducing ring’ is shown. A previous investigation in our lab indicated that this direction congruency is critically dependent on the spatial relationship between the inducing ring and test ring dots at the final moment the inducing ring is shown. We have also observed, however, that this congruency effect is diminished when the inducing ring presentations are short (< 30 ms), suggesting that processing that occurs before the final moments of the inducing ring presentation contributes to the congruency effect. In the two experiments of the present study, we divided the inducing ring presentation period into three contiguous temporal segments, and compared the effect of reversing the ring's rotation direction in the first, middle, and last of these segments. A direction reversal of any of the segments reduced the congruency effect. When the test ring followed the inducer, the reversal during the final segment had the largest, and the reversal in the initial segment had the smallest effect. When the test ring preceded the inducer, however, the reversal during the initial segment had the largest and the reversal in the final segment had the smallest effect. These results imply the processes that determine the direction of the illusory rotation are active throughout the inducing ring presentation, with the intervals closest in time to the test ring onset having the greatest impact.

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Can activated long-term memory content influence target verification in visual search?

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According to Guided Search theory (Wolfe, 2021) visual search is controlled by two representations. Guiding template is held in working memory (WM) and determine what objects would be selected. Target template is held in activated long-term memory (ALTM) and matched against selected objects for target verification. A bunch of studies showed that WM is pretty good in preventing interference from irrelevant information (Bartsch, Oberauer, 2023). While little is known about the influence of ALTM content on target verification process. According to first approach, representations in temporal storage are decaying over time. It’s needed to be rehearsed to stay available for processing (Hurlstone, Hitch, Baddeley, 2014). According to second approach, representations are suffering of an interference caused by other memory content (Oberauer, Lin, 2023). We address this issue by manipulating memory load semantically related/unrelated to a target during a visual search task. We hypothesized, if a target template is decaying over time, semantically related memory load would help for rehearsal which would decrease target verification time (compare to unrelated memory load). However, if a target template suffers of interference, semantically related load would increase target verification time. Fifty-six volunteers (3 males) aged from 18 to 28 (M=19) were asked to perform a visual search task among real-world objects while maintaining three words semantically related or unrelated to a target. A target was designated by its’ basic category label. We measured dwell time on target using Eyelink Portable Duo (1000 Hz). Repeated measures ANOVA shows no effect of Memory load on target verification time $F(1,55)=0.068$, $p=0.795$. We conclude that a target template is not decaying while maintaining in ALTM but also it does not suffer of interference from semantically related words. Supposedly an activation of perceptual features related to remembered words was too weak to cause an interference and influenced target verification.

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Modeling the Relationship Between Stimulus Characteristics and Visual Attention: An Eye-Tracking Study

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Background: Natural environments' complexity influences visual attention, specifically change detection. Stimulus characteristics such as distractors, interest, congruency, and social relevance play a key role. Eye-tracking was used to analyze a comprehensive model to assess visual stimuli's primary influences and interrelations on change detection. Objective: To investigate the influence of stimulus characteristics on visual attention using a change blindness paradigm with eye-tracking. Methods: The gaze behavior of 50 university

students (19-31 years, M=23, SD=2.2, 38 female) was recorded as they viewed 64 image pairs for 360 ms, interrupted by 120 ms black screens, until detecting an item change via mouse click. The area of interest (AOI) highlighted item changes. Statistical Analysis: A multilevel model was used to identify the main effect of the eye-tracking measurements on change detection. Stepwise regression was employed to determine which stimuli characteristics significantly predict change detection. Results: Response times were the main contributor over the first fixation or duration time and visits on the changing item to change detection. Model 1 initially incorporated centrality versus marginality of change, accounting for 16% of the variance ($F(1, 782) = 149.001$, $p < .000$). Subsequently, Model 2 introduced the number of distractors, enhancing the variance explained to 23.7%, marking a significant increase in the model's explanatory capacity ($F(1, 781) = 79.184$, $p < .000$). Model 3 further added congruency versus non-congruency, achieving a 27.8% variance explanation ($F(1, 780) = 43.715$, $p < .000$), and Model 4 incorporated social relevance as the final predictor, slightly elevating the explained variance to 28.3%, remaining statistically significant ($F(1, 779) = 5.348$, $p = .021$). Conclusions: This analysis highlights the complex interplay of stimulus characteristics in influencing visual attention and underscores the importance of considering multiple factors for accurately predicting how individuals perceive and interact with their environment in varied populations.

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Scene context influences gaze orientation on objects in peripheral vision

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Peripheral vision plays a critical role during scene categorization. The rapid extraction of global features in peripheral vision would allow a rudimentary representation of the scene, known as the gist, associated with prior knowledge about regularities in the visual environment. This knowledge could then be used to rapidly categorize the scene, but also to generate predictions about objects it contains. Previous studies suggest that predictions generated from peripheral vision improve the categorization of objects in central vision. However, visual perception is a dynamic phenomenon which alternates between ocular fixations on an object of interest and saccades towards the periphery to fixate new objects. The present study aims to investigate how predictions based on the scene context in peripheral vision influence gaze orientation on objects in peripheral vision. Twenty-five participants performed a go/no-go saccadic task on an object (either animal or furniture) displayed in peripheral vision (7° of eccentricity), either on the left or the right side of a central fixation. A scene background was simultaneously displayed in peripheral vision, either semantically congruent with the object (outdoor scene/animal and indoor scene/furniture) or incongruent (indoor scene/animal and outdoor scene/furniture). Participants were instructed to make a saccade towards the object belonging to a target category or maintain fixation at the centre when it belonged to the distractor category. When the target object was absent (and thus, the distractor object was present), participants made more false alarms towards the distractor in an incongruent scene (but congruent to the target object) than in a congruent one. This suggests that scene context influences gaze orientation on objects in peripheral vision. We are currently conducting a new study in which we manipulate the onset asynchrony between scene and object to further investigate the influence of predictions based on scene-context on gaze orientation in peripheral vision.
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Light-level dependent changes in the temporal properties of the center mechanism of cat X-cells

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Cat X-cells have historically been studied as a model for the human P-cell. Here we have sought to characterize how the temporal properties of the center mechanism of X-cells change over the full operational range of light levels encountered by the cat. Comparing impulse and temporal frequency responses it was found that the X-cell center could be considered to respond as a linear system at each adaptation level. As a result, a linear model of temporal filtering was possible for each light level. The responses for both photopic and scotopic light levels could be modeled well with a five parameter temporal filter model, although the models for the two ranges had somewhat different forms. While the form of the models did not change for different adaptation levels in the photopic and scotopic ranges, the parameters of the models did, providing quantification of the changes in temporal properties with light level. The description provided by our data constitutes perhaps the most complete description of the changes in temporal properties with light level currently available for a retinal ganglion cell.
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Two-dimensional sound cues can speed visual search

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Visual search is a classic paradigm for studying vision and attention. It is well known that searching for the absence of a feature can be very slow and demanding. We also know that cross-modal cues are highly effective at re-orienting attention. Here, we combined these ideas to explore whether effortful serial search could be speeded when target location was simultaneously cued by a spatially informative 2D sound. Search arrays consisted of a 4 x 4 grid containing simple, schematic faces. All faces appeared to be wearing spectacles, except a randomly positioned target, where a single line representing the bridge of the frame was removed. We compared search with and without a predictive sound cue. When present, the sound cue began at display onset and continued until a response was made. In this initial experiment, we used 4 levels of pitch to cue the grid rows: lower pitch was mapped to lower rows (frequency steps :262, 523,

1046, 2093 Hz; corresponding to piano C octaves 4 through 7). We used 4 levels of tempo to cue the grid columns: slower tempo was mapped to the left of the grid (tempo interval parameters: 800, 600, 400, 200 ms; covering a range slightly wider than from adagio to prestissimo). By combining these pitch and tempo parameters, each grid cell could be uniquely cued. Participants (N=20) performed four blocks: the initial and final blocks with no sound (pre-test and post-test, respectively), and the two experimental blocks with sound. Search was significatively speeded in the blocks with sound (M=2584; SE=72.5) compared to either of the blocks without sound (M= 3357; SE = 100.6). These findings suggest that 2D auditory cues can be used to guide spatial attention during visual search.

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Evaluating Dynamic Random Dot Stimuli for Binocularity Assessment: Toward a Standardized Clinical Protocol

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This study aims to devise a reliable stimulus and experimental setup for objectively assessing stereopsis clinically using steady-state visually evoked potentials (ssVEPs). Dynamic random dot stereograms (DRDS) are widely accepted for selectively examining stereopsis. These stimuli can generate various binocular percepts, including spatial surfaces and depth changes over time. Our objective was to identify the most effective stimulus that consistently elicits statistically significant ssVEP responses across a diverse participant pool. Significance was determined using the T2circ statistic at $p<0.01$. The ssVEPs were recorded from eight young adults with intact stereopsis at 10 standard electrode positions, with each stimulus lasting at least 90 seconds. DRDS stimuli were used, each one showing a checkerboard pattern of near and far disparity regions that alternated in depth. This type of stimulus is insensitive to monocular artefacts and a response is expected only if stereopsis is present. The check size was 1 degree and the disparity was ±5.46 min of arc. The stimulus frequencies were 0.94, 1.33, 1.88 or 2.66 cycles per second. To score the reliability of each stimulus, we counted how many times any of the Oz, O1 and O2 channels showed significant response at either the fundamental or first harmonic frequencies for all participants. According to our current data, the most reliable stimulus was the depth-reversing DRDS checkerboard of 2.66 cycles per second frequency, which produced significant responses in 83% of the measurements. The other frequencies produced similar, but lower reliabilities (63%, 60%, and 63% for 0.94, 1.33 and 1.88 cycles per second, respectively). In summary, our results suggest that the ssVEP response elicited by depth-reversing DRDS stimuli can be used as an objective marker of stereopsis, although the reliability of the response may depend on the stimulus frequency.
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Motor-related subcortical pathways are involved in subjectively unconscious tool processing

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Extensive behavioral and fMRI studies have suggested the significance of subcortical pathways for residual action abilities within blindsight, revealing that visually guided actions can be accomplished unconsciously. However, the specific involvement of the subcortical pathways in visuomotor transformation, especially under the unconscious condition, remains elusive in healthy humans. Tools are special among various object categories because each tool corresponds to a particular action. Here, we employed functional magnetic resonance imaging to investigate the representation of tools (toolness, tools vs. non-tools) within subcortical structures when tool images were made invisible using continuous flash suppression (CFS). Both univariate analysis and multivoxel pattern analysis (MVPA) revealed a significant tool representation in the left thalamus, with the left ventral anterior (VA) thalamus, a motor-related subregion of the thalamus, as the most important thalamic subregion. In the basal ganglia, the left striatum exhibited robust toolness representation in both univariate analysis and MVPA. Only area 9a (part of the dorsolateral prefrontal cortex) and anterior 10p (orbital and polar frontal cortex) demonstrated significant toolness representation among cortical regions. Surprisingly, however, areas in the parietal and middle temporal cortex that showed stronger activation for tools than non-tools in previous studies did not show a difference in activation in the subjective unconscious condition here. Functional connectivity results indicated that, compared to elongated non-tools, elongated tools increased the connectivity between the bilateral VA thalamus and left 9a and between the right VA and left STR in the basal ganglia in CFS. Notably, dynamic causal modeling results unveiled a feedforward thalamocortical pathway from the left VA to the left 9a, contributing to toolness representation in CFS. These findings unveiled the involvement of the motor-related subcortical structures, particularly the ventral anterior thalamus and basal ganglia, and a thalamocortical pathway in the visuomotor transformation of healthy humans engaged in subjectively unconsciousness.
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Behavioural relevance of foveal cortex processing for haptic size estimation

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Human neuroimaging work shows that the foveal cortex is recruited during haptic exploration of objects, in the absence of visual input. Here we ask: is haptic processing of object properties in the foveal cortex relevant for behaviour? To this aim, we tested 30 individuals in a behavioral paradigm (Experiment 1). Participants used their right-dominant hand to haptically explore one of three differently sized cylinders placed behind a monitor, while fixating a central cross. During the haptic exploration, dynamic visual noise was presented in

central vision (Noise condition) to disrupt haptic processing in the foveal cortex, if present. In a control condition, no visual noise was present. Subsequently, participants were asked to manually estimate the size of the explored stimulus. We then tested 20 volunteers (Experiment 2) to investigate whether the effects of dynamic visual noise on haptic size estimation may be explained by: 1) foveal processing, 2) the contribution of bimodal cells with overlapping visual and somatosensory receptive fields, 3) attentional distraction. To test these hypotheses, we adapted the previous behavioural paradigm such that in noise trials the dynamic visual noise randomly appeared in the center, on the right or left side of the screen. Results of Experiment 1 show that stimulus size is overestimated in the Noise as compared to control condition, suggesting uncertainty when the visual noise is present. Results of Experiment 2 reveal no significant effect of visual noise location on performance, suggesting that none of the tested hypotheses alone can explain the results of Experiment 1. While the results of Experiment 1 suggest that the foveal cortex supports haptic size estimation, further research will explore if multiple mechanisms could explain these effects.
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Effects of adaptation to a hue-rotated altered-reality environment on categorical colour constancy and unique hues

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Research on the effect of long-term adaptation on colour perception has mainly relied on simple colour transformations using filters or manipulations of chromatic contrast. Altered reality (AR) enables adaptation to a broader range of manipulations to be investigated. Whilst most AR studies have investigated non-chromatic adaptation (Bao & Engel, 2019), Grush et al. (2015) examined the effects of adaptation to colour-manipulated environment on the colour perception of two participants. Participants reported a disruption in colour constancy following adaptation to a hue-rotated world. Here we further investigated the effect of long-term adaptation to a hue-rotated AR on colour constancy and unique hues, using calibrated psychophysical tasks and appropriate control conditions. We adapted participants to a hue-rotated world (e.g., sky becomes red) using an AR device (Meta Quest 3) that had a passthrough image of the real world. The passthrough image was manipulated with a rotation of hue in HSL space in real time, and participants were exposed to either a positive, a negative or no hue rotation. Participants adapted to the altered environment for 4 hours, during which they interacted with a rich chromatic diet of natural scenes, paints, objects, and fruits. Before and after adaptation, participants' categorical colour constancy and focal chip identification under three illuminations was measured (Olkkonen et al., 2010), as well as participants' unique blue and yellow hues (Webster et al., 2000). We also recorded participants' introspections during and after adaptation for qualitative analysis. Our results can inform us about the types of transformations that the visual system can adapt to. Participants' introspections whilst living in an altered chromatic reality and immediately after also provide insight into the role of colour in daily life.

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Uncertainty processing in Schizophrenia - electrophysiological evidence of alterations in intensity and temporal precision

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Sensory information is inherently noisy and ambiguous. This has to be resolved by the perceptual system to construct stable and reliable representations of the world. Recent EEG studies found large amplitude differences between processing of perceptual uncertainty vs. certainty ("ERP Uncertainty Effects"). These effects, evoked by stimuli from very different stimulus categories (geometry, motion, size, Gestalt perception, emotion), are interpreted as correlates of reliability estimations of perceptual outcomes. Such mechanisms are proposed to be altered in psychiatric disorders like Schizophrenia. In this study, we investigate ERP Uncertainty Effects in patients with Schizophrenia and possibly impaired underlying mechanisms. ERP Uncertainty Effects were evoked in patients with Schizophrenia (N=18) and matched neurotypicals (N=17) by presenting smiley faces with varying visibility levels of emotional expressions. We calculated peak amplitudes of the ERPs, and via a time-frequency analysis the respective total power and ITC (inter-trial phase coherence). We found a highly similar pattern of ERP Uncertainty Effects in patients compared to neurotypicals, however with generally smaller peak amplitudes. We found less ITC in patients compared to neurotypicals, whereas power was not group-dependent. Correlating ERPs with power values, we found no significant correlations in neurotypicals, and lower amplitudes with lower power in patients in some conditions. Correlating ERPs with ITC values, we found higher amplitudes with higher ITC in all conditions in neurotypicals, and only in some conditions in patients. Recent evidence suggests that temporal imprecision is fundamental to impairments in patients with Schizophrenia in general, and to reduced ERP amplitudes specifically. Our study highlights the contribution of both millisecond-level temporal imprecision and reduced intensity of neural processes to lower ERP amplitudes in patients with Schizophrenia during uncertainty processing. These findings align with predictive coding models and suggest that time-frequency analyses help to unravel underlying mechanisms of electrophysiological alterations in psychiatric disorders.
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Monocular delay during active vision shifts ocular dominance

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Delaying information in one eye by 330ms for 1h during an active visuomotor coordination task (building a tower from blocks) is sufficient to transiently shift ocular dominance in favor of the delayed eye (Steinwurzel et al, Current Biology, 2023). Instead, passively viewing a

third person performing the same task does not affect vision, despite the same visual delay. This leaves open the possibility that the sight one's own movements (egocentric perspective) is critical for monocular delay to shift ocular dominance.13 participants performed three experiments that measured ocular dominance balance before and after one hour visual stimulation, using an altered-reality system. The first experiment was a replication of the original, with participants actively engaged in a tower-building task in a VR setup that delayed signals to the dominant eye by 330 ms. Like in our previous study, this transiently shifted ocular dominance in favor of the delayed eye. In the second experiment, participants passively watched the video recorded during the first experiment. Although the visual stimulation was identical as in the first experiment, it did not lead to a shift of ocular dominance, indicating that active engagement in the task is necessary. The third condition replayed the video in one eye and blanked the other, reproducing a standard monocular deprivation condition; the effect of this third experiment was statistically indistinguishable from the first experiment with active tower-building. We conclude that an active visuo-motor active task is necessary for delayed visual input to induce ocular dominance plasticity, as passive viewing from an egocentric perspective is not sufficient.

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Exploring Non-Human Primate Symmetry Perception

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Decades of psychophysical studies underscore the significance of symmetry in human visual perception. Symmetry is characterized by its automatic, rapid, and robust processing, with sensitivity to vertical and horizontal symmetry axes. Additionally, the presence of multiple axes in mirror symmetry enhances symmetry detection accuracy while reducing reaction times (RTs). Despite recent delineations of a symmetry cortical network in non-human primate visual cortical areas, a gap persists in our understanding of symmetry perception. Our study aimed to evaluate a rhesus macaque's ability to discriminate symmetric and phase-scrambled non-symmetric stimuli using a two-alternative forced-choice paradigm. Symmetry stimuli were regular textures with mirror symmetry. Initially, we explored the influence of symmetry axis number by presenting stimuli with either single (horizontal or vertical) or dual axes of reflection (combining both horizontal and vertical). Additionally, we varied the orientation of single-axis symmetric stimuli from 0° to 150° in 30° increments to examine the effect of orientation on discrimination. Consistent with human findings, rhesus macaques easily discriminated symmetric stimuli, reporting accuracy for symmetric stimuli and for non-symmetric. Surprisingly, RTs were significantly longer for symmetric versus non-symmetric stimuli, suggesting increased engagement in screening symmetry patterns. Interestingly, while increasing axis number improved symmetry detection in humans, double-axis symmetry exhibited significantly higher RTs compared to single axes (horizontal or vertical), with slightly lower performance in monkey. Single-axis orientation manipulation revealed significantly better performance of symmetry detection around cardinal axes (0° and 90°) compared to oblique ones, mirroring human observations. In both experiments, a sustained greater pupil dilation was observed during symmetry stimuli presentation compared to non-symmetry, as previously observed in human. Overall, these behavioral studies reveal that, like humans, macaque can easily discriminate symmetry, possibly through a mix of similar and different mechanisms, shedding light on the complexity of symmetry perception.
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Impact of rhythmic movements on perception of realness of silicone-based artificial skin

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The distinction between silicone-based artificial skin and living human skin primarily lies in their capability for motion. Silicone objects remain static unless acted upon by an external force, whereas living human tissue exhibits subtle movements due to physiological functions such as breathing and heartbeat. These movements can significantly influence perceptions of skin appearance. This study aimed to explore the effects of rhythmic movements on the realness of silicone-based artificial skin. Participants evaluated silicone sheets with circular visible windows, assessing their realness and uncanniness. Two conditions were compared: a skin condition resembling human skin in color and texture and a control condition featuring a gray sheet with black dots. Four rhythmic motion conditions were applied to the silicone sheets (inflation and return repetitions) at 0, 20, 40, and 80 beats per minute (bpm), with a vertical motion extent of approximately 3 mm. Results indicate that perception of skin realness was higher in the skin condition than in the control condition, peaking at approximately 20–40 bpm in both cases. Furthermore, uncanniness increased linearly with movement speed in the control condition, whereas no such trend was observed in the skin condition. These findings suggest that specific micromotion patterns contribute to increased animacy and realness in artificial skin without significantly adding to its uncanniness.
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Dot clouds' perceived area for varying regularity is greater than that of respective convex hull polygons

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One critical aspect of visual patterns is the interaction between their various characteristics. For instance, in numerical estimation research, features such as the total element area and element density significantly influence perceived numerosity. Density, while mathematically well-defined by considering both the number of elements and the area enclosed by a definite border, often fails to align with perceptions of dot clouds, which lack defined boundaries. In this work, aiming to understand how the visual system integrates information from dot ensembles to estimate area, we investigate whether the convex hull serves as a reliable proxy for the perceived area of dot clouds, a common approach in literature. Observers compared pairs of patterns to select which appeared larger in area. Each pair consisted of a dot cloud (N = 20) and the same dot cloud enclosed by its convex hull after being rotated randomly. Both dot cloud and polygon patterns served as reference in half of the trials. The test pattern's convex hull area varied as a fraction of the reference

convex hull area. To assess the impact of dot organization on area perception, we used patterns ranging in regularity, manipulating regularity by applying varying degrees of positional jitter to a square lattice of dots initially placed within a circular aperture. Data from five observers were analyzed by fitting a cumulative Gaussian psychometric function. Results indicated that for all levels of regularity and across all observers, the dot cloud was perceived to be of the same area as the polygonal pattern when the polygonal pattern was noticeably magnified. The points of subjective equality (PSE) in terms of area magnification were significantly different to 1 (1.28, 1.24, 1.51, 2.03, and 1.31) for all subjects, across all jitter levels. No consistent dependency of PSE on dot regularity was observed.

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Subsequence search errors are less for targets embedded in a collinearly grouped structure

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In visual search, accuracy for the first target is usually higher than the second target, which is a phenomenon known as the subsequence search errors. Previous studies showed that a more salient target (e.g., brighter than other items in the search display) showed fewer subsequence search errors. This study aimed to explore whether a target embedded in a collinearly grouped structure can also reduce subsequence search errors. Two experiments, each with 20 participants, were carried out. In Experiment 1, a search display with a collinearly grouped structure was applied, and the target could either be on the collinear structure (on-target), in the background (off-target) or not shown (0-target). Results showed that on-targets were more accurate than off-targets. Experiment 2 added a two-target condition to the 0-target and 1-target conditions. While in the two-target condition, an on-target and an off-target would be presented. Results showed that on-targets had a higher accuracy than off-targets in the two-target condition. Our findings suggest collinear grouping facilitates visual search and avoids subsequence search errors.
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Human Attention is All You Need: Fine-tuning Image Encoder with Attention Heatmaps

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Exploring the subjective nature of conscious experience highlights the difficulty in understanding the experiences of other beings. While objective facts about creatures are within reach, grasping their subjective experiences remains challenging due to our inherent subjective perspectives. To bridge this gap, our research explored the feasibility of transferring the human attention system to a transformer-based Image Encoder by refining its latent space with human attention heatmaps. We collected averaged heatmaps for 50 images from CAT2000 dataset, highlighting the areas that individuals focused on during a visual description task. These heatmaps were then incorporated into the Image Encoder's fine-tuning process. By comparing the linguistic outputs before and after the heatmap transfer, along with human evaluation of stimuli, we observed a significant impact on the model's performance, particularly in stimuli related to social contexts. These results provide valuable insights into enhancing machines' human-like qualities by aligning their attention with human behavior, offering a pathway to better understand and replicate complex cognitive processes.

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The task effect on Main Sequence

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Saccades' kinematic is well defined through the Main Sequence (MS) that links saccade amplitude, duration, and peak velocity. While a study showed that the MS is repeatable under different experimental conditions (Gibaldi & Sabitini, 2021), another study found that it differs between voluntary and involuntary saccades (Kaminiarz et al., 2009). In the same way, deviations from the MS had been observed for saccades recorded during scene exploration which might be explained by interactions with the visual scene content (Costela & Woods, 2019). Our aim was to compare the MS variability for visually-guided and free-viewing saccades in a large group of participants. Method: 58 participants were eye-tracked. In Experiment 1 (Exp.1), they had to make saccades as fast and accurately as possible towards small peripheral targets that appeared on the left or right side of a central fixation at various eccentricities (2, 4, …, and 12°). Accurate saccades (±1° around the target position) were used to compute individual MS. In Experiment 2 (Exp.2), they had to freely explore 60 images of natural scenes for 3 seconds each. Only horizontal saccades were analysed (±5° from horizontal). A two-parameters exponential model of individual MS was estimated for both experiments using bootstrapping. For each amplitude bin, the mean absolute percentage errors (MAPE) were computed between peak velocities estimated by the MS model and those observed for visually-guided (Exp.1) and free-viewing (Exp.2) saccades. Results: Individual MS were significantly different between experiment and the mean MAPE scores were higher for Exp.2 than for Exp.1 for all amplitude bins and even higher for larger amplitudes. Conclusion: The MS varies with the saccades type (visually-guided or free-viewing). These results need to be discussed considering the fact that MS also depends on others factors like saccade latency, saccade gain and target size.

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Do we judge robots like humans when they give us incorrect information?

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Through engaging with others socially, we can quickly and accurately form impressions of them based on their behaviour (their social value) and what we get from them (their reward value). When others' negative social value is incongruent with their positive reward

value, most place more importance on the behaviour rather than the outcome when forming an impression. This work sought to investigate if similar patterns exist when interacting with social robots to better understand how people might build trust and liking with robots. It was hypothesized that the negative impressions participants form towards robotic stimuli would not be as strong as the negative impressions towards human stimuli. Participants played a card game in which they were tasked with guessing if the value of a hidden card was higher or lower than a revealed card. They were aided by four unreferenced faces, two robots and two humans. One robot and one human would always look towards the correct answer (the veridical faces) whilst the remaining two would always look towards the incorrect answer (the non-veridical faces). Importantly, these gaze cues were deterministic – once participants learned which faces indicated the right answer and which the wrong, they could easily use either piece of information to discern the correct answer. As a consequence, participants were equally accurate with, and earned the same amount from, veridical and non-veridical faces. Therefore, all faces had positive economic reward value, but non-veridical faces that may be perceived as deceptive, had negative social value. When judging strangers, participants liked humans and robots equally. However, participants judged the non-veridical robot more harshly than the non-veridical human and liked the veridical robot less than the veridical human. This suggests that robots may benefit less from positive social value and suffer more from negative social value than their human counterparts.
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Using Visual Category Learning to Evaluate Category Representations in Conditional Generative Adversarial Networks

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Generative adversarial networks (GANs) are a recent technique to approximate the generative model underlying any corpus of data. GANs hold great potential as a tool for cognitive and vision science, equipping researchers with the ability to generate a theoretically infinite number of well-controlled, complex visual stimuli. Several early GAN applications show great promise in shedding new light onto important topics in cognitive science. However, to unlock the full potential of GANs, we need a better understanding of the correspondence between human and GAN representations. In the present project, we evaluate the category representations developed by conditional GANs using human visual category learning. Specifically, we asked whether humans can learn to categorise class-specific GAN-generated images, and if so, whether they can generalise that knowledge to real samples. Two groups of participants first learned to categorise either real or GAN-generated histology samples depicting benign or malignant breast cancer. After learning, all participants were probed for generalisation to novel samples from both image sources. Categorisation performance, as indexed by sensitivity and bias, showed no reliable differences between groups during training. During generalisation, categorisation performance with samples matching the image source seen during training was maintained. Most critically, categorisation performance seamlessly generalised across image sources: participants trained with GAN-generated samples were as sensitive and unbiased in categorising real samples as those trained with real samples, and vice versa. These results support a close correspondence between how humans and deep networks represent natural categories. We discuss future research avenues exploiting the categorical knowledge developed by GANs to revisit classical findings built upon simplistic stimuli (such as Gabor patches). Also, in a more applied vein, we underscore how these findings might help design training schedules that speed up the development of visual expertise.
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Looking from different angles: Alternative perimetry methods complement each other

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Introduction: Standard automated perimetry (SAP) is difficult to perform by various patient groups and can be unreliable. The requirement for sustained fixation over the course of testing and the need for giving feedback in form of a button press often leads to retakes and is a strain on patients and ophthalmological care units. Recently, various attempts have been made to design perimetry methods that overcome some of these limitations. The novel methods rely on different, but potentially complementary information. In the current study, we compare two novel approaches for assessing the visual field in two separate participant groups with respect to their individual and complementary effectiveness for detecting and reconstructing visual field defects. Methods: Data was acquired by having participants view 1-min movie clips while their gaze and pupil size were recorded with an eye tracker. Both a gaze-based and a pupil-size-based method were applied on the data from 32 participants with glaucoma and 20 participants with hemianopia and compared to a similar number of visually healthy control participants. The gaze-based approach relies on contrasting saccade characteristics of participants with a visual impairment and age-matched controls. The second approach uses the pupil data obtained in the same measurements. Results: Preliminary results showed that the saccade-based approach was particularly reliable at discriminating participants with glaucoma from controls. However, results in the hemianopic participants were less precise and may have been affected by adaptive viewing strategies. In contrast, the pupil-based method was not affected by this and reliably categorized quarter- and hemifield damage but underperformed in segregating participants with glaucoma from controls. Conclusion: We conclude that the results obtained using novel perimetry methods that are based on movie-watching data complement each other. In particular, a data-driven combination of their visual field predictions may therefore become a suitable alternative to SAP.

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Costs of Switch between Perceptual Discrimination Tasks of Unequal Strength

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The ability to switch between goals in response to environmental stimuli is essential to function effectively in dynamic and complex multitasking environments. While cognitive control allows for rapid adjustments of cognition in accordance with newly relevant tasks, this flexibility comes with performance costs. These costs are traditionally studied in situations where people switch between tasks that involve static, simple and unnoisy stimuli that are unrepresentative of most real-world performance environments. In the present study, we examined task-switching performance with tasks more reflective of the processing demands of complex operational environments, incorporating dynamic, complex and noisy stimuli. In a cued task-switching paradigm, participants had to respond to random-soldier kinematograms (with soldiers as stimuli objects instead of dots) that had two properties: soldiers' motion direction and uniform colour. Participants had to discriminate the prevalent direction of motion (motion task) or the prevalent uniform colour (colour task) in two types of experimental blocks: pure blocks (trials of same task) and mixed-task blocks (both tasks presented randomly, resulting in task-switch or task-repeat trials). A difference in task strength derived from stimulus-response compatibility (S-R mapping was aligned with the direction of motion in the motion task, but was arbitrary in the colour task). Two performance costs were assessed: mixing cost (pure minus single-task trials) and switch cost (task-switch minus task-repeat trials). The results showed significantly poorer performance (slower and more error-prone) in task-repeat trials than in pure trials, indicating mixing cost, as well as in task-switch than in task-repeat trials, indicating switch cost. Switch cost was also found to be asymmetric: larger switching costs in switching to the (dominant) motion task than to the (weaker) colour task than in the opposite direction. This provides evidence that, in task-switching situations, a dominant task receives more inhibition than weaker ones to counteract task-set carry-over to subsequent trials.

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Internal Representation of Facial Emotions in Schizophrenia

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Schizophrenia is associated with atypical emotion recognition, but there is variability in the results which highlights the limitations of using fixed facial configurations to measure emotion recognition. We used a genetic algorithm (GA) approach that allows participants to create facial expressions of emotions, resulting in an estimate of their unique internal representations of facial emotions (Binetti et al., 2022). 21 individuals with schizophrenia (female=7; mean age=37.5, SD=8.83) and 21 typical individuals (female=13; mean age=30.9, SD=11.5) used the GA to create computer-generated facial expressions to represent happiness, fear, and anger. Across 8 iterations, participants selected expressions (maximum of 10 per iteration) that represented the target emotion. The selected faces were recombined to create the next iteration of faces in a process that imitated evolutionary breeding with mutations, converging on a final facial configuration (termed "elite face"). Each sample face was defined by weights on 150 blendshapes, which are avatar expression features. Our analysis was focused on 40 core blendshapes that approximate biologically plausible facial muscle actions as captured by FACS. Principal component analysis was applied to subjects' elite faces and the principal components (N=17) that explained 68.7% of the variance were selected for further analysis. We measured the dissimilarity between subjects' elite face and the neutral face (distance from neutral), as well as subjects' elite face and the average elite face for each emotion category across groups (distance from centroid). We found a nonsignificant effect of clinical group on distance from neutral ($F(1)=0.9$, $p=.34$), but that the distance from centroid was significantly higher for individuals with schizophrenia compared to typical individuals ($F(1)=5.1$, $p=.03$). These findings suggest that impairments in emotion recognition in schizophrenia may result from increased variability in their internal representations, which may be poorly suited to standard methods of testing.
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Investigating the relationship between dyadic person similarity and face judgement similarity

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Research shows that perceivers consistently extract information from faces to judge whether others are attractive, trustworthy or dominant. However, there is also substantial variability among perceivers when making these social judgments. We seem to use our own dispositions as frameworks for making judgements about others, so could it be that two people who are similar in their dispositions also tend to make more similar social judgements? A consistent understanding of others may serve as a foundation for our social relationships, be it platonic or romantic. The present study investigated whether dyadic similarities in participants' own dispositions are related to similarities in their social face judgments. 307 participants based in the UK rated 24 faces on 6 social traits. Participants also rated themselves on 13 social traits and completed a 60-item personality questionnaire. We computed dissimilarities between pairs of participants for face judgments, self-perceived trait ratings, and personality ratings, resulting in three separate dissimilarity matrices. Each entry in each matrix depicted pairwise distances in ratings between participants. Using representational similarity analysis, the three matrices were then correlated with each other. Results showed that both the self-perceived trait and personality matrices were significantly correlated with the face judgement matrix ($rho=0.13$, $p<.001$ and $rho=0.19$, $p<.001$, respectively). These results indicate that participants with more similar personalities and social trait dispositions were more likely to make similar social face judgements. Importantly, these associations were stable even when controlling for age, gender, ethnicity, and geographical location (Self-perceived traits: $\beta=.19$, $R^2=.061$, $F=613.69$, $p<.001$; Personality: $\beta=.19$, $R^2=.078$, $F=795.01$, $p<.001$). These findings show that people who are more similar to each other also perceive the world in a similar manner. This may form the basis for how we gravitate towards others, build connections and form relationships.

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The flexibility of cue combination in response to new physical and social information

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We live in an ever-changing environment, requiring our information processing systems to remain flexible to experiences we make throughout life. A central process that would offer such flexibility is cue integration: driven directly by the instantaneous reliability of sensory cues as well as long-term established predictive priors, cue integration sits at the intersection of perception and cognition. Yet, we know little about its plasticity in adulthood. Two distinct, yet important contexts in which cue integration can offer considerable flexibility is via: (1) increasing perceptual precision by adopting novel cues to physical environmental properties, and (2) adjusting perceptual representations by their direct self-relevance. In a series of studies, we assessed how flexible cue integration is to the physical and social context. Firstly, we assessed whether and how adults learn to integrate novel, auditory cues with familiar, visual disparity cues to enhance depth perception precision. Using large-sample (n = 60) and small-sample (n = 8) training paradigms, we show that robust inter-individual differences exist and persist despite perceptual training. This suggests not only limited flexibility towards sensory experience in adulthood, but also pre-existing differences in the propensity to integrate specific cues. Secondly, we assessed whether audio-visual integration is malleable to instantaneously induced self-relevance. By measuring perceptual biases, our results show that integration is modulated by social relevance, depending on the individual's self-bias strength. Computational modelling suggests that social modulation functions similarly to perceptual priors, allowing individuals' self-representations to exert a stronger or weaker influence on perception. Taken together, these findings show that cue integration offers flexibility in how we perceive and respond to our environment, specifically through the modulation of priors. However, they also suggest that stark individual differences exist in the flexibility to adopt novel sensory cues, highlighting the need to adopt a stronger focus on individual differences in contextual flexibility.
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Symmetry as a Cue to Animacy

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Pareidolia is the tendency to perceive meaningful structures, such as faces, in images where none exist. Images with vertical symmetry have been found to be particularly potent sources of pareidolia. However, it is yet to be established whether images with vertical symmetry elicit the perception of more meaningful structure in general or whether the effect of symmetry is specific to animacy-related percepts. Here, participants were shown greyscale images of fractal noise patterns and instructed to report any structure that they perceived. Overall, there was a greater number of responses for stimuli that were symmetrical around the vertical mid-line than for purely random patterns. This was also true when either animacy-related responses or inanimate responses were isolated. Crucially, however, the proportion of animacy-related responses was consistently higher for vertically symmetrical images. Thus, not only do vertically symmetrical images elicit the perception of more meaningful structure in general, they also lead to a disproportionately high number of specifically animacy-related percepts. We suggest that the finding that vertical symmetry serves as a cue to animacy can be understood as follows. Even if an object is symmetrical, it will only generate a symmetrical image on our retina if it is viewed from a particular viewpoint. If that object tends to orient itself towards us then the chance of a symmetrical image resulting is greatly increased. Thus, given a vertically symmetrical image, it is likely that the source itself is animate and our visual system is correspondingly likely to arrive at an animate interpretation.
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The tolerance for changes in eye size on perception of face identity

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Recently we have been able to easily manipulate our mug shots, e.g., changes in eye sizes and shape of facial contours, etc. However, excessive manipulations of facial photographs sometimes let us perceive even familiar people as different people. This phenomenon suggests that we have some threshold for facial manipulations to tell the faces as identical. In the current study, we examined the tolerance for changes in eye size on the perception of facial identity. Thirty-two young adults participated in the experiment to ask whether two images of adult female faces presented sequentially were perceived as the same person or not. Each participant was tested with 12 conditions: the same condition (two stimuli were the same identity and veridical depiction: 0%), the different condition (two stimuli were different identities), and the eye-size-manipulated conditions (10 conditions: two stimuli were the same person, but the eye size of one stimulus was manipulated from -100% to +100% in increments of 20%). We calculated the mean percentage of responding "same" in each condition. First, we confirmed that participants responded correctly for the same (88.91%) and different (2.03%) conditions, with significant differences from chance level (50%). Second, when the eyes were expanded (between +20% and +100%), participants perceived two face stimuli as different persons even with the eye size difference of 20%. In contrast, when the eyes were contracted (between -20 % and -100%), the eye size difference of 60% was needed when participants perceived two face stimuli as different persons. These results imply that (1) we may perceive two faces as different people not only when manipulating the spacing of facial features (e.g., Le Grand et al., 2001) but also when manipulating the size of facial features itself, (2) we have a different sensitivity between to the expansion and contraction of eyes.

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Prior Scene Information Facilitates Face Detection in Natural Settings

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Humans show a remarkable ability to rapidly and accurately detect faces across various scenes. However, the extent to which scene context and visual features influence the rapid detection of faces remains largely unexplored. Here, we investigated how prior scene information affects face detection behavior and identified visual features critical for detecting faces in natural settings. We curated a stimulus set of 120 natural scenes from 12 indoor categories, each containing a single face. For each image, we annotated both basic image features (e.g. face size) and extracted high-level visual features using CNNs. To assess the effect of prior scene information, we generated face-less versions of each scene. In an eye-tracking experiment, 38 participants performed a face detection task while we measured the latency until their first saccade landed on the face. Before each target scene, participants viewed a brief preview (250 ms) of either the face-less scene or a neutral gray screen. We found that faces were detected significantly faster in the preview condition than in the no-preview condition (mean time to fixation: 207 vs. 216 ms; $p<0.001$), with detection latency also varying significantly by scene category ($p<0.001$). An encoding model analysis revealed that visual features explained varying amounts of variance in face detection latency, with most variance explained by high-level CNN features. Interestingly, all features explained significantly less variance in the conditions with prior scene previews. Our results show that prior information about a scene enhances human face detection capabilities and that existing feedforward models fall short in predicting face detection latency in those scenarios, suggesting the need for more complex, possibly recurrent neural network models to fully capture these visual processing mechanisms. Overall, our study elucidates the role of scene context in face detection and advances our understanding of the critical features underpinning face processing in natural settings.

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Perception of angry facial expressions is enhanced by somatosensory cues for avoidance

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Our previous study reported that self-avoidance behaviors facilitate the perception of others' facial expressions as angry (Kobayashi et al., ECVP2023). However, unknown is which avoidance-behavior factors promote the perception of angry facial expressions. Thus, this study conducted a psychophysical experiment to identify the causes by focusing on changes in somatosensory and visual cues. A 3D avatar stimulus's facial expressions in a virtual reality space varied from happy to angry. Participants wore a head-mounted display and were asked to do either of the following before judging the avatar's facial expression: 1) move away from the avatar; 2) move away from the avatar while keeping spatial relations between the participant, avatar, and room (only provided somatosensory cues); 3) not move but participants see a video in which the participant moved away from the avatar in the first-person view (only provided visual cues); and 4) not move and just see the avatar. The results showed that the avatar's face in Condition 2) was perceived as the angriest, suggesting that somatosensory cues to avoid the avatar facilitate the perception of angry facial expressions, even if visual cues for self-avoidance, were not provided. Additionally, the participants interpreted this context as being followed by an avatar that threatened them, suggesting that this context may have facilitated the perception of angry facial expressions. Therefore, these findings suggest that somatosensory cues enhance angry perceptions of others' facial expressions and the context as being followed by others may operate it.
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Abstract shapes show affective traits

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Two experiments are presented concerning the Takete/Maluma phenomenon, which involves presenting participants with two abstract shapes (one curvy/roundish, the other angular/pointy) and two non-words (one characterised by a 'smooth' sound, the other by a 'sharp' sound). Participants tend to associate the curvy shape with the smooth sounding non-word, and the angular shape with the sharp sounding non-word. Our research expands on such phenomenon by investigating the correspondence between abstract shapes and affective traits. In experiment 1, 122 native Italian speakers were presented with nine abstract shapes and ten non-words: three characterised as sharp sounding, three as soft sounding, two as mixed sounding, and two which sounds may remotely recall the name of geometrical figures (tigano for triangolo-triangle; kiquoda for quadrato-square). Each shape was presented singularly, and participants had two tasks: 1) choose a name for the shape among the list of non-words; 2) select an affective trait that best described the shape (good, bad, angry, sad, scared, joyful, calm, pleasant, bored, melancholic). In Experiment 2, 193 native Russian speakers saw the same visual stimuli; the tasks associated with each shape were three: 1) choose a name for the shape from the list of non-words (transposed into Cyrillic); 2) choose a non-word that best describes the shape from a list of non-words (the Italian affective words transposed into Cyrillic); 3) select an affective trait that best described the shape from the list of words translated into Russian (experiment 1, task 2). Results: a) the naming task did not lead to clearcut results in either experiment; b) the assignment of affective traits (task 2 exp. 1; task 3 exp 2) were practically identical in both experiments; c) the assignment of non-words derived from Italian affective words transposed into Cyrillic (task 2 exp. 2) was basically random, not influenced by how they sound.

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Realness of face images can be decoded from non-linear modulation of EEG responses

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Artificially created human faces play an increasingly important role in our digital world. However, the so-called uncanny valley effect may cause people to perceive highly, yet not perfectly human-like faces as eerie, bringing challenges to the interaction with virtual agents. At the same time, the neurocognitive underpinnings of the uncanny valley effect remain elusive. Here, we utilized an electroencephalography (EEG) dataset of steady-state visual evoked potentials (SSVEP) in which participants were presented with human face images of different stylization levels ranging from simplistic cartoons to actual photographs. Assessing neuronal responses both in frequency and time domain, we found a non-linear relationship between SSVEP amplitudes and stylization level, that is, the most stylized cartoon images and the real photographs evoked stronger responses than images with medium stylization. Moreover, realness of even highly similar stylization levels could be decoded from the EEG data with task-related component analysis (TRCA). Importantly, we also account for confounding factors, such as the size of the stimulus face's eyes, which previously have not been adequately addressed. In this work we thus established an objective approach for detecting uncanny valley effect using neural recordings which in turn can be the basis for characterization of artificially created human faces. As a next step, we generated a new, more naturalistic dataset of face images with subtle changes from cartoon to real faces, which we envision – together with normative ratings of perceived realness and appealingness acquired in an online study – to serve as a basis for further studies on the realness perception and the uncanny valley effect.
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Reading acceleration training combined with bilateral parietal beta-tACS ameliorates reading and gaze control in dyslexia

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Developmental Dyslexia (DD) is a neurodevelopmental disorder affecting approximately 10% of the population, characterized by impaired reading efficiency resulting from suboptimal letters/words segregation and saccadic control. These deficits are likely to depend on dysfunctions of the magnocellular dorsal (M-D) stream. Mounting evidence linked specific functions of the M-D stream to the beta-band (15-25 Hz) activity in the parietal cortex. In the present study, we combined reading acceleration training with high-definition transcranial alternating current stimulation (tACS) to increase reading speed in adults with DD. Participants (N = 27) took part in a 12-session training protocol and were allocated to two different training groups that performed a reading acceleration task for 40 minutes in each session. Concurrently with the task, the tACS group received beta (18 Hz) tACS over bilateral parietal sensors while the Sham group received a placebo stimulation. Before and after each session, resting-state EEG, self-paced reading speed, and gaze were recorded. Results showed that for slower readers, self-paced reading speed increased faster throughout sessions in the tACS group compared to Sham. Moreover, the tACS group also showed a faster reduction of regressive saccades across sessions with respect to the Sham group. Resting-state EEG showed differential modulations of beta power and frequency between the two groups throughout the training and also changes in the aperiodic component (i.e. exponent) of the spectrum. These results suggest that modulation of parietal beta activity may strengthen the efficacy of visuo-attentional reading training and optimize oculomotor control in DD. Moreover, they show that multi-session beta tACS impacts neural oscillations and excitation/inhibition balance, potentially promoting plastic changes in the brains of individuals with DD.
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Frontoparietal Transcranial Random Noise Stimulation Reveals Hemispheric Asymmetry in Visuo-Spatial attention

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Objectives: Using an 'attentional isolation' behavioral paradigm (forcing subjects to perform a 30-min unilateral task, while being presented with a bilateral task), we have recently demonstrated that this manipulation results in a subsequent increased performance in the 'isolated' visual field. The present study aims to replicate and extend these results by combining behavioral intervention with brain stimulation (tRNS). Specifically, we sought to explore the repercussions of attentional isolation in the contralateral, isolated visual field, concomitant with the application of tRNS. Material and Methods: Sixty-five participants were enrolled in this study. We used a bilaterally presented Multiple Objects Tracking (MOT) task, where subjects were asked to track a subset of dots among distractors. Subjects were randomly assigned to two different manipulation groups. Group 1 performed right unilateral MOT, Group 2 performed a left unilateral MOT. During the unilateral manipulation, subjects had to actively ignore one hemifield (isolated) while performing the task in the attended hemifield. In a counterbalanced order, subjects underwent both sham and active stimulation. tRNS was delivered at 2mA, at 101-640Hz. Results: We found prolonged unilateral tracking increased performance in the isolated visual field in the sham condition. However, unilateral right active tRNS nulled the post-manipulation benefit of attentional isolation. Conversely, unilateral left tRNS maintained the post-isolation benefit. This reveals a hemisphere dependent response to stimulation. Discussion and conclusions: The study observed an asymmetry in response between left and right frontoparietal stimulation. This difference may be explained by the different neural responses of the two hemispheres when engaged in a sustained visuospatial task. Consequently, it unveils the potential to modify hemispheric balance through frontoparietal tRNS, leading to a dissociation in responses between the left and right hemispheres. Crucially, this study may open new rehabilitation strategies for spatial neglect.

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Rapid visual motion priming effects partially explained by response artefacts rather than perceptual effects

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Motion aftereffects have been widely studied to better understand mechanisms of adaptation that can arise after exposure to a particular direction of motion for several seconds. There is also evidence that adaptation, as well as motion direction priming, can arise with much shorter timescales on the order of tens to hundreds of milliseconds. In such studies, directional motion stimuli (e.g., gratings drifting left or right) have been presented for very brief intervals and followed by an ambiguous motion stimulus with, in some cases, only tens of milliseconds of between the two stimuli. For the briefest directional stimulus durations and shortest inter-stimulus intervals, the ambiguous stimulus tends to be perceived as having the same direction of motion as the preceding directional stimulus (i.e., priming). For longer directional stimulus durations and intervals, adaptation has been shown (i.e., different perceived directions of motion). Here, we replicate these rapid priming and adaptation effects but demonstrate that at least some of the rapid priming effects can be attributed to participants' inability to resolve two separate stimuli in the very brief presentations required to elicit these effects. In our experiments, in addition to asking about perception of same/different motion, we also assessed participants' ability to distinguish whether only one or two stimuli were present. Our data suggest that participants tended to perceive only one stimulus at the short stimulus durations and inter-stimulus intervals and were biased towards "same" responses which, artefactually we argue, indicated "priming". In contrast, when participants correctly perceived two separate stimuli, they were much less likey to show priming effects. Thus, we argue that previous results did not represent a true rapid priming effect. Instead, we argue the results arose artefactually from the task and response constraints. Previous results demonstrating rapid visual motion priming need to be reassessed in light of these findings.

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Eye-guided video games improve reading in healthy older adults

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Aim: This study aimed to explore the effectiveness of a custom-built eye-guided video game in improving visuomotor, visual, and attentional skills involved in reading in healthy older adults. Method: Forty healthy participants aged over 65 were included in the study. They underwent a battery of cognitive, visual, attentional, and reading tests to assess their initial cognitive performance and register changes after a training period. Only the experimental group (N=19) performed training sessions with three custom-built eye-guided video games aimed to train saccades, fixations, and pursuit movements. Specifically, the first eye-controlled video game was "Gamabunta", for training attention, saccades and fixations; the second was "No Remora", to train attention and pursuits; and the last eye-guided video game was "Umbrella" aimed at training attention, fixations, saccades and pursuit. Participants in the experimental group performed ten sessions, each made of 45 minutes, two times a week over five weeks. The control group (N=21) underwent the assessments before and after the same time but did not engage in any training. Results: Only participants in the experimental group improved their reading and visual abilities. Specifically, after the training, they showed a decrease in reading time, a reduction in the number and duration of fixations, and an increase in the amplitude of saccades. Furthermore, improvements in contrast sensitivity and the perception of near vision quality (NAVQ) were registered in the training group after the training. Instead, no changes in attentional parameters were observed. Conclusion: Our findings indicate that custom-built eye-guided video game training enhances reading abilities and oculomotor performance in healthy older individuals without direct training in reading. This could be due to an improvement in basic oculomotor and visual skills, emphasizing the potential benefits of this approach for cognitive enrichment in healthy older adults.

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Spatiotemporal processing in dyslexia

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Purpose: An investigation of fine spatial judgements perturbed by a brief temporal gap in one case, and motion on the other, in people with dyslexia to understand whether people with dyslexia's (known) impaired temporal perception impacts on their ability to make fine spatial judgements which is crucial for reading. Methods: Thirty adult participants were recruited in this study. They were equally separated between the two groups and were demographically comparable. A temporal order judgment task of two stimuli rapidly presented was performed to measure the temporal acuity in addition to a bisection spatial task which consists of two flanking bars and a bisector which flashes in between to measure spatial acuity. The spatial task had three different test modes: static, jitter (where stimuli jitter around in Brownian motion), and a static with a temporal gap between flankers and the bisector. Also, to characterise dyslexia, reading ability tests and an intelligence test were performed in addition to visual stress symptoms tests. Results: In agreement with the literature, a distinguished temporal processing deficit in people with dyslexia was observed. Spatially, and despite dyslexics being less precise in every test mode, the difference between groups was not significance. Similarly, thresholds were slightly/insignificantly higher in dyslexia group. The temporal deficit in dyslexia mildly correlated with reading ability performance and visual stress symptoms. Conclusion: People with dyslexia have poorer spatiotemporal processing compared to controls. The temporal deficit in dyslexia correlates with both reading skills and stress symptoms which warrants further investigation.

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Looking to the past: differences in oculomotor activity between verbal and visuospatial maintenance

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Evidence suggests that eye movements can be biased toward action- and memory-relevant locations. While the link between oculomotor behaviour and planned actions has been studied extensively, it is not yet clear what factors modulate memory-driven eye movements.

We investigated oculomotor activity during maintenance of verbal and visuospatial representations using a paradigm that allows the disentangling of rehearsal from output preparation. To achieve this, we presented participants with a list of seven digits or squares within a grid on one side of the screen and asked them to recall on the opposite side either the full list (Experiment 1) or three retro-cued items (Experiment 2). Both experiments revealed that during maintenance the encoding side was both more likely to be fixated and was fixated for longer in the square recall task compared to the digit recall task, with no clear memory benefit or cost associated with this pattern. These findings add to a growing body of research by investigating oculomotor rehearsal of a list of items and by suggesting the type of representation to be maintained as a key predictor of post-encoding eye movements.

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Bayesian adaptive estimation of high-dimensional psychometric functions using particle filtering

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Interesting stimulus spaces are often high-dimensional, making exhaustive measurement of perceptual decisions infeasible. This creates the need for adaptive experimental methods that efficiently explore the space. Current adaptive methods are either not suited to classical, well-characterized psychophysical tasks (e.g. Gibbs Sampling with People) or do not scale well to more than 4 dimensions (e.g. QUEST+). Here, we propose a particle filtering approach to approximate the posterior distribution of a multidimensional (logistic) psychometric function with lapses online. Even for high dimensions it is fast enough to update the posterior between trials (order of 1 sec). This posterior allows one to select the next stimulus in the experiment such that the expected information gain is maximized. In simulations, we show that with this method the entropy decreases between two and three times faster than when sampling stimuli randomly for a 15-dimensional feature space (18-parameter psychometric function, with a 15-dimensional hyperplane, an intercept, lower and upper asymptotes). We test the algorithm in simulations up to 50 dimensions and find that it is still fast and reliable. We validate the algorithm in a human experiment on facial gender categorization. For faces of the Chicago Face Database, we compute Active Appearance Model features (around 500 000 dimensions), perform dimensionality reduction to 15 dimensions using PCA, and then create a pool of new face images by morphing between faces in the 15-dimensional space. Human participants label the faces as “male” or “female”. The adaptive method is more than twice as efficient as random sampling in terms of entropy minimization, but predictive performance shows mixed results. Overall however, models created with our adaptive technique allow the measurement of perceptual decision functions in stimulus spaces that were previously infeasible.
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Visual perception of naturalistic actions in the theoretical framework of perceptual decision-making: An EEG study

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Previous neuroimaging studies have identified distinct regions in the posterior parietal cortex that are selective for observing different action classes, such as locomotion, self-directed, and manipulative hand actions. Behavioral studies investigating these classes using perceptual discrimination tasks further provided evidence of differences in decision parameters between the aforementioned action classes. A counterpart of a decision variable signal in the brain, the centro-parietal positivity (CPP), has been commonly observed in perceptual decision-making tasks facilitating simple or artificial stimuli such as random-dot motion; however, whether its existence and properties can be generalized to more complex and natural action stimuli remains unclear. In the present study, human participants (N=17) completed three EEG experiments in which they were asked to discriminate between two action exemplars of a specific action class (i.e., locomotion, self-directed, or manipulation). We created four coherence levels for each exemplar to inject noise into the decision process. Our behavioral results show that the response times and miss-rates decreased as the coherence level increased. On the other hand, EEG results showed that CPP was elicited in all three experiments, with its peak amplitude tracking the coherence level of the stimuli. A repeated measures ANOVA on the mean amplitude of CPP indicated the main effects of action class and coherence level. These results suggest that the decision-making mechanisms involved in the visual perception of natural actions share similarities with those active for simpler stimuli but action classes differ from each other in terms of certain decision variables.
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Lightness of the 3D virtual objects under two illumination levels

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Although the visual system is mostly exposed to scenes with three-dimensional (3D) objects under multiple illumination levels, most lightness models were designed for scenes containing two-dimensional (2D) objects. However, in the case of multiple illumination levels object’s lightness is computed based on its parts in the higher illumination (HI) and the parts in the larger field of illumination (LFI). In this study, we wanted to test whether such rules can be further extended to real 3D objects as well as to virtual environments. In the E1 (N=36) real 2D and 3D objects were placed in an apparatus where shadow covered half of their surface. In E2 (N=40), the same scene, illumination, and stimuli from E1 were virtually recreated (in graphics software BLENDER) and presented on a CRT display placed inside the same apparatus. The same E2 setup was used in E3 (N=30) but with a virtual shadow enlarged to cover most of the object’s surface. In all 3 experiments a real Munsell scale was placed inside of the apparatus and the lightness matches were collected for the whole objects and for differently illuminated object parts. In E1&2, the lightness of the whole object was determined only by the matches from the parts in the HI. In E3 object matches were a compromise between matches from the parts in the HI and the parts in the LFI. Therefore,

a comparable pattern of results was obtained for object matches for both real and virtual stimuli and for 2D and 3D stimuli. Based on such results, we can conclude that the HI and LFI rules can be extended to 3D and virtual objects.

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Cross-modal matching of brightness and loudness, and internal references

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'Make the light as bright as the sound is loud.' This is a typical instruction in experiments dealing with the cross-modal matching of stimuli. According to the theory of global psychophysics (Luce, Steingrimsson, & Narens, 2010; Heller, 2021), in such a cross-modal task, the perceived stimulus intensities are judged against respondent-generated internal reference intensities, all represented on a common psychological scale. The internal references are distinguished with respect to their role in the experimental setup, that is, whether they pertain to the standard or to the comparison stimulus in the matching task. By testing the theory of global psychophysics on cross-modal data, the present study aims at thoroughly investigating the role-sensitivity of the internal reference intensities. Therefore, we replicate a classical experiment by Stevens and Marks (1965), whose participants adjusted the brightness of a light to the perceived loudness of a noise sound and vice versa. Complementing the traditional group-level analysis, we evaluate and model the data on the individual level. We find that the cross-modal matching curves differ in slope, and show a regression effect as reported in the classical literature. In order to experimentally manipulate the internal references' role-(in)dependence, we discuss a paired comparison task with an adaptive staircase procedure as psychophysical method. With it, the subject is instructed to indicate the more intense stimulus. So there is no 'standard' or 'comparison' stimulus for the subject and the internal references are expected to be role-independent. As a result, the 'regression effect' should vanish.

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A network analysis of factors of visual hypersensitivity and symptoms of anxiety

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Increased subjective sensitivity to certain visual stimuli (e.g., repeating patterns, bright lights) is known to vary in the general population, and also associate with several clinical conditions (e.g., migraine, synaesthesia, autism). We recently developed a novel questionnaire measure based on bifactor modelling, the Cardiff Visual Hypersensitivity Scale (CHYPS-V), which assesses four highly replicable factors of visual hypersensitivity. These include brightness (e.g., sunlight), repeating patterns (e.g., stripes), strobing (e.g., light flashes), and intense visual environments (e.g., supermarkets). We used this measure in a large general population sample (n = 1841) to investigate whether visual sensitivities show similarities across clinical diagnoses and areas of neurodiversity. Hypersensitivity to intense visual environments was found to be particularly useful in distinguishing visual sensitivities experienced by individuals with clinical diagnoses from those without, and differential patterns of sensitivities were established upon controlling for comorbid diagnoses. As anxiety was a common comorbidity, subsequent analyses took a network approach to understand the shared structure of visual sensitivities and anxiety symptoms more specifically. The resulting network was stable, and bridge strength analyses identified sensitivities to intense visual environments and feelings of panic as key bridge nodes. This suggests that somatic symptoms of anxiety, as opposed to excessive worry, may be important in understanding the development of visual sensitivities, and their association with anxiety more broadly. This network analysis has subsequently been replicated (n = 595) using an alternative measure of anxiety, with comparable results found across individuals both with and without autism. Overall, this work will be important in informing future causal design which considers how intervening in central nodes could affect anxiety symptoms and aversive visual experiences, and enhance understanding of the complex, interacting systems that contribute to these networks.
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Temporal Properties of Pupillary Synchronization During Human Communication

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Conversations between individuals involve the subtle coordination of non-verbal and verbal processes. This coordination can emerge on a behavioural level but can emerge on a physiological level, as well. Previous research has shown pupillary responses, a measure of autonomic regulation, tend to synchronize between individuals during communication and that the strength of this synchrony is indicative for the amount of engagement to the conversation. However, the exact temporal properties of the alignment in pupillary responses during communication remains unclear. Specifically, it is unknown whether dialogue is characterized by precise synchronization in pupil dilation between interlocutors or if systematic leader-follower relationships can be observed across communicating dyads. Here, we collected pupillometry data from dyads engaging in a variation of the cooperative party-game, Heads-Up. While playing, the roles assigned to participants were varied so that each participant spent half of the game as the “questioner” and the other half as the “responder”. Synchrony in pupil dilation within each dyad was assessed using cross-wavelet power analysis, which provides information concerning the degree of cross-correlation between signals across a range of frequencies and local temporal windows to gain insight into leader-follower relationships. Results revealed that cross-wavelet power was highest on average within the frequency range of 0.06 Hz to 0.12 Hz. Within these frequency bands, a significant phase shift was observed, indicating leader-follower relationships that change systematically with the role of the participant in the Heads-Up game, rather than observing precise synchronization. Together, these insights shed light on the complex spatiotemporal dynamics of pupillary responses during interpersonal communication.

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Can changes in pupil diameter cause illusory visual motion?

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A well-known motion illusion can be seen in stationary patterns that contain repeated asymmetrical luminance gradients, which create a sawtooth-like spatial luminance profile. Such patterns can appear to move episodically, triggered by saccadic eye movements and blinks. The illusion has been known since 1979, but its origin is still unclear. Our hypothesis is that episodes of the illusory movement are caused by transitory changes in the retinal luminance of the pattern that accompany reflexive changes in pupil diameter following eye movements, blinks and pattern onsets. Changes in stimulus luminance are already known to cause impressions of motion in static patterns that contain asymmetrical luminance gradients. To test the hypothesis, participants viewed static illusion patterns and made controlled blinks or saccades, after which they pressed a button to indicate the cessation of any illusion of movement. We measured changes in pupil diameter up to the point at which the illusion ceased. Results showed that both the amplitude and the duration of pupil dilation correlated well with illusion duration, consistent with the role of retinal luminance in generating in the illusions. This new explanation can account for the importance of eye movements and blinks, and for the effects of age and artificial pupils on the strength of the illusion. A simulation of the illusion in which pattern luminance is modulated with the same time-course as that caused by blinks and saccades creates a marked impression of illusory motion, consistent with the hypothesis that temporal luminance change generates the illusion.
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How do expectations in potential information gain influence saccade decision and performance?

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Saccades bring selected objects from the environment into the high visual acuity fovea, allowing detailed analysis. Target selection could be driven by the expected information gain after foveation. Saccades towards high informational value regions would be facilitated compared to other less informational regions. We designed a saccadic decision task to study the effect of a decrease in information value for a specific region of the visual field. We examined how participants learned this information value map alteration and how this impacted decision processes. We also tested whether this informational value map update generalized to other oculomotor tasks. In a learning phase, two identical peripheral Gabors were simultaneously presented on every trial, under four configurations (0°-180°, 45°-225°, 90°-270°, or 135°-315°). Participants knew that the Gabors were the same but they had to select and foveate one of them to be able to discriminate the orientation. For each Gabor position, 20% of trials included noise superimposition at the end of the saccade making the discrimination impossible. For a given region (different between participants), this noise level was increased to 80%, diminishing the informational value of this region. Results showed that participants tended, on an idiosyncratic rate, to decrease their probability of choosing Gabors in the altered region. This probability change was used to compute a responsiveness index for each participant. For participants with higher responsiveness only, both latency and accuracy of saccades made toward the altered region increased. Basic reactive saccades and more internally-generated saccades tended to show a preference for non-altered regions following the learning phase. Together, results illustrate how a learned distribution of informational values in the visual field impacts saccadic decision making and performance, in order to maximize expected information gain. They also suggest that various oculomotor behaviors may share a common informational value map.
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Exploring the neural basis of individual gaze in complex scenes

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Recent research has demonstrated systematic individual differences in observer gaze when freely viewing complex scenes, with prominent differences in the tendency to fixate faces, bodies and text. What is the neural basis of these individual biases? Independent strands of developmental work in humans and non-human primates suggest ties between category-specific salience and corresponding neural preferences in the ventral stream. Here, we conducted a two-part study with participants freely viewing 700 complex scenes in an eye-tracking session, followed by a second, fMRI session. In the scanner, participants completed a standard localizer paradigm, aiming to identify specific patterns of activity for six different object categories (face, body, limb, word, house and car) in the inferior temporal cortex (IT). To date, we have tested 26 healthy adults (with a target of 60), who showed reliable differences in fixation biases towards text, faces, bodies and limbs. We also observed substantial individual differences in the distinctiveness of corresponding patterns of IT activity, a measure that has recently been associated with the development of category-specific neural preferences. Notably, we found first evidence suggestive of a link between the immediate attraction of gaze towards faces and text during free-viewing and the distinctiveness of corresponding IT patterns in the fMRI session ($r = .41$, $p = .04$ for text, $r = .37$, $p = .07$ for faces). This suggests that people with a stronger tendency to fixate faces or text also have a more distinct representation of the corresponding stimulus category in the ventral stream, a finding that needs to be corroborated by the full dataset once complete. Furthermore, we plan to test a potential relationship between spatial individual saccadic biases and corresponding anisotropies in early visual field maps. Taken together, we hope to learn how individual brains shape individual gaze and, ultimately, our perception of the world.
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People do not automatically avoid regions in which feedback about their movements is occluded

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In daily life, people constantly make rapid choices. They choose where to place their feet on paths and their fingers on objects they are grasping. When doing so they consider posture, and energy expenditure, but also uphold precision. An interesting question concerning the latter is whether people automatically avoid moving in a manner in which the visual feedback about their own movement is occluded. This could happen if an opaque item hides the moving limb, or if the limb moves through the blind region of a person with scotomas. To examine whether anticipating occlusion influences rapid choices, we asked participants to perform a simple task in which there were always three targets on a screen. The participants' task was to move the cursor to any of the three targets as quickly as possible. Once they reached a target, three new targets appeared. The background had regions of three different grey levels along the paths to the three targets, such that the grey cursor was invisible for some time if it moved to one of the three targets. Participants did not avoid the path along which the cursor disappeared, regardless of whether the cursor's grey level changed with the appearance of new targets or remained constant. Since it hardly took longer to reach targets when the cursor disappeared under these conditions, we gradually made reaching the target without feedback more difficult until it did take longer. When it took longer, participants avoided moving through the background that hid the feedback to some extent. These findings suggest that people do not automatically select movement paths in which they will have feedback, but learn to avoid certain regions if they experience that moving through them results in poorer performance.
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Characterising the Neural Dynamics of Object-Based Attention in the Presence of Hemispheric Competition with M/EEG

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Selective attention is known to enable the brain to prioritise task-relevant information. However, the interaction between this top-down controlled prioritisation and the brain's inherent hemispheric dominance remains unclear. We investigated this question using concurrent magnetoencephalography (MEG) and electroencephalography (EEG) recording combined with multivariate pattern analysis (MVPA). In our task, participants viewed two visual objects from different categories on each side of the screen, selected the target based on its semantic category (fish, boat or chair), and reported its colour (red, green or blue). The categories of both the target and non-target object could be decoded from the pattern of activity across sensors, from approximately 80 ms after stimulus onset. Category coding was initially similar for target and non-target, but target object coding was stronger than non-target coding from around 370 ms. Subsequently, we performed source reconstruction and decoded object categories using data from the left and right visual, posterior parietal, and prefrontal cortices. We found that each hemisphere coded for visual information from both sides of space, though contralateral decoding was significantly stronger. We then examined the interaction between hemispheric dominance and attention by analysing the decoding differences between contralateral and ipsilateral objects. Contralateral decoding consistently outperformed ipsilateral when the contralateral object was the target, lasting until 700 ms. However, when the contralateral object was non-target, the contralateral advantage was shorter lived, lasting only until 360 ms. This pattern was most pronounced in the visual cortex, less so in the posterior parietal cortex, and minimal in the prefrontal cortex, where overall decoding performance was lower across conditions. Our findings suggest that while hemispheric lateralisation dominates the early stage of visual processing, as the task progresses, the brain gradually discards irrelevant information to form a more global state focused on encoding task-relevant information.

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Visual Reference and its Impact on Consumer Assessment of Medication Dosage

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In Switzerland, the introduction of the prescription 1g tablet (in addition to the common 500mg tablet) of paracetamol led to significantly more hospital admissions due to unintentional overdoses. A change in dosage is just one of the many causes of the increased risk of unintentional paracetamol overdoses in consumers. The question is, can visually presented warnings in the sense of reference information enhance consumers' accuracy in assessing medication dosage. To investigate this, participants (N = 324) in an online study were presented with a fictitious medication package containing 1g or 500mg paracetamol tablets (factor: dosage) and with no or a visual reference illustrating the correct dosage for adults (factor: reference). Participants then had to indicate, among other things, the maximum daily dosage in tablets, with the possibility of adjusting their answers after consulting a package insert (factor: pre/post package insert consultation). Significant main effects were observed for the between-subject factors dosage and reference (both p's < .001), with participants exposed to the 1g paracetamol dosage and the visual reference indicating significantly higher maximum daily dosages. The within-subject effect of package insert consultation was also significant ($p < .05$), indicating adjustments of participants' answers after package insert consultation. The significant dosage x pre/post package insert consultation interaction for the adult reference group, for example, shows that the 1g group adjusts their assessments less than the 500mg group. Hence, contrary to expectations, the provision of a visual reference did not improve dosage assessment accuracy. Furthermore, participants prescribed with 1g paracetamol dosage consistently indicated excessively high maximum daily dosages, even after consulting the package insert. These

findings show the importance of exploring alternative strategies to enhance consumer awareness and mitigate the risk of medication overdose.

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No automatic post constancy representations of symmetry

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Imagine a symmetrical arrangement of dots on a flat surface, such as a piece of card. When the card is viewed face on, in the frontoparallel plane, the retinal image is also symmetrical. However, when the card viewed from an angle, the retinal image is not symmetrical. EEG studies have found that visual symmetry generates an Event Related Potential (ERP) called the Sustained Posterior Negativity (SPN, Makin et al., 2022). SPN amplitude is larger for frontoparallel than perspective symmetry when participants attend to dot luminance (Makin et al., 2015). We predicted that this perspective cost would be reduced if additional visual cues were available to support 3D interpretation. After all, shape constancy feels subjectively effortless: We rarely notice the changing shapes in our retinal image as we move and adopt different vantage points. We measured perspective cost on SPN amplitude in four EEG blocks (N=120, within subjects design). These were 1) the baseline block with no supporting cues 2) a monocular viewing block, 3) a block where a frame was presented before stimulus onset, and 4) a block where a moving frame was presented before stimulus onset. Despite our pre-registered predictions, perspective cost was similar in all four blocks. We conclude that the brain does not construct a post constancy representation of symmetry under these conditions. Shape constancy may not be as ubiquitous as introspection leads us to believe.

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Prediction-dependent biases in orientation oscillate in synchrony with saccades at alpha frequencies

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Perception of a continuous world relies on our ability to integrate changing and discontinuous sensory signals, including signals at the time of saccadic eye movements. In this study, we examined behavioral oscillations at the time of saccades to uncover how pre-saccadic prior information influences the perceived orientation of a subsequent test stimulus during the saccade. In the task, a pre-saccadic prior stimulus (a high-contrast grating patch) was briefly presented for 17 ms, after which participants made a horizontal or vertical 16° saccade. At a random delay from saccadic target, the test stimulus, a brief 17-ms Gabor patch of six possible orientations (±35º, ±45º, ±55º), was displayed in the center of the screen. Participants (N = 24) reproduced the orientation of the test (in total 17327 trials). The orientation judgments showed a strong average bias towards the orientation of the prior (serial dependence), especially when the test stimulus appeared near saccadic onset, consistent with strong integration of past with current information during peri-saccadic perception. In addition to the average bias, orientation judgments oscillated in synchrony with saccade onset at two frequencies. When averaging data over all prior stimuli (so their effects cancel out), orientation biases oscillated at beta rhythms (~18 Hz), towards the cardinal axes. Superimposed on the beta rhythms were strong oscillations at alpha frequencies (~9 Hz), towards the orientation of the prior (similar for horizontal and vertical saccades). Oscillations in serial dependence suggest that alpha rhythms may be instrumental in communicating perceptual expectations across saccades, helping to preserve stability in the face of eye movements.

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Cross-modal reliability defeats the central tendency effect

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Several studies have shown a tight relationship between task domains and sensory modalities. Namely, vision is the most reliable sense for processing spatial information, while audition is for time. Nevertheless, when the best modality is not available, perception could become ambiguous, causing a reduction in performance. To resolve such ambiguity, our brain may utilise contextual information and prior experience. One contextual effect is central tendency, where perception shifts towards the average of a set of stimuli experienced in prior encounters, usually in the same modality. What happens when there is a potentially more reliable source of prior experience in another modality? To test if perception in one sensory modality can benefit from a more reliable cross-modal prior, we used an estimation task in which participants had to estimate the temporal duration or the spatial distance of randomly presented stimuli that were either auditory or visual. The average of each type of stimulus was different and all differed from the overall mean. Therefore, it was possible to test which of the three means influenced perception. We tested this hypothesis in both a spatial and a temporal estimation task. In both tasks, perception in the less reliable modality (audition for space, vision for time) was biased towards the more reliable modality, which suggests that the most influential contextual information is modality-based rather than central-tendency-based. Furthermore, we tested various prior models to see which best fitted the experimental data, finding that the best model relies on priors from the most reliable modality for the task. In conclusion, we find that the brain, to resolve perceptual ambiguity, can discriminate and utilize the best contextual information available in any sense at that moment.

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Influences of Neural Oscillation Phase on Perception of the Tilt Illusion

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Rhythmic influences on neural processing have been shown at multiple levels from synapse to behaviour and have inspired many theories of the role oscillations may play in neural computation. Despite these convergent findings, the results of studies testing an association between neural oscillation phase (e.g., a wave's peak vs. trough) and human perception are inconsistent. Several null results have emerged in studies of phasic influences on visual discrimination, prompting questions about whether oscillatory influences on neural processing have any impact on perceptual outcomes. In recent theoretical work, we proposed reasons why oscillation analyses may be insensitive when associated with higher-level visual functions, potentially producing spurious null results. Here, we followed up on that work, testing for an association between oscillation phase and visual discrimination in a low-level visual effect, the direct tilt illusion, in which the perceived orientation of a central grating is biased away from the angle of an oriented surround. We titrated a central grating to each participant's perceived-vertical angle in the presence of an oriented surround of ±30°. We then had them make forced-choice reports of whether the central 'vertical' stimulus was rotated clockwise or counter-clockwise on each trial while we measured their brain activity with EEG. We replicated the direct tilt illusion in both surround conditions. Furthermore, we found that the likelihood of participants making an 'illusion-consistent' (i.e., repulsive) response fluctuated with the power and phase of pre-stimulus neural oscillations in the 8-14 Hz 'alpha' range, consistent with an influence of these oscillations on the strength of the illusion on single trials. These results explain one source of across-trials variance in perceptual reports of the direct tilt illusion and confirm that neural oscillations influence visual discrimination, consistent with their broader role in neural communication and coordination.
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The emergence and calibration of magnitude integration between duration and numerosity

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Magnitude dimensions such as duration and numerosity are not perceived independently from each other, but are often integrated leading to mutual influences. For instance, a set of items can be perceived as more or less numerous depending on its duration, and vice versa. The nature of this integration effect is however still debated. Do different dimensions interact based on an absolute, intrinsic relationship (i.e., association between long duration/high numerosity)? Or is the integration calibrated according to the short-term stimulation statistics? Here we address these questions by tracking how magnitude integration emerges over time and how it adapts to changes in the magnitude of the stimuli. We used dot-array stimuli modulated in duration and numerosity, spanning different ranges in different blocks of trials. Participants judged either one dimension or the other in different sessions. The results show that the integration effects emerge briefly after an initial calibration, and that different effects show different sensitivity to changes in the magnitude range. Namely, the duration effect disappeared when changing range, but re-emerged rapidly when returning to the initial calibrated range. The effect of numerosity showed instead a less stable dynamics, and needed re-calibration even when returning to the initial range. These results demonstrate that magnitude integration emerges relatively to the specific magnitudes a subject is exposed to, and that once calibrated it does not immediately transfer to different magnitude ranges. Overall, our findings support the idea that magnitude integration arises from perceptual processes tuned to the statistics of the environment.
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Causal effects of rhythmic TMS on behaviour in visual short term and working memory tasks

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Working memory (WM) and short-term memory (STM) are often used interchangeably in cognitive neuroscience literature, yet they denote different cognitive processes. Short term memory refers to the temporary storage of information, whereas working memory involves additional goal-directed manipulation of this information. Previous studies have shown correlational as well as causal evidence for involvement of brain oscillations at alpha (8-12Hz) and theta (4-8Hz) frequencies in the maintenance stage of visual WM/STM but without explicit differentiation of these two processes. Here, we investigate the causal relationship between oscillatory neural activity and behavioural performance in a task where participants had to either mentally manipulate the maintained information (WM) or not (STM). In a change detection task, participants (N=15 so far) were retro-cued to maintain all stimuli (polygons and gratings) during a delay period (STM condition) or only stimuli belonging to one feature category (polygons or gratings), while ignoring non-cued stimuli (WM condition). Importantly, the retro-cue indicated the stimulus category, but not the visual field, to remember, thereby engaging feature-based memory processing. In the first MEG part of this study, we found increased theta (7Hz) activity associated with mental load in the STM condition, and increased inhibition-related high-frequency alpha (11Hz) activity in the WM condition. Here, we applied alpha and theta rhythmic transcranial magnetic stimulation (rhTMS) at these frequencies in the same participants, during the maintenance stage of the task, while concurrently measuring EEG. TMS was guided by the MEG results (right intraparietal sulcus and right dorsolateral prefrontal cortex for alpha and theta, respectively). Rhythmic TMS had little effect on behavioural performance measured with accuracy and reaction times, due to large inter-individual variability in a) memory capacity; b) response to TMS stimulation, in line with previous reports. Currently we are exploring the predictive power of various neural factors in explaining individual variability in entrainment.
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Talk Session 6 - Face Perception

Super-Recognizers or Su-perceivers

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Face identity processing ability varies substantially in the general population—even among so-called "Super-Recognizers". Their behaviorally measured advantages include face recognition and identification, but recent neuroimaging evidence suggests that their processing superiority may be broader still—extending beyond faces. In 3 experiments we isolated such individual differences among super-recognizers and controls using subprocess-specific face identity processing neuromarkers, to explain performance on taxing behavioral face identity processing tests. Experiment 1 measured neuromarkers of face identity discrimination during 60s image sequences of a single repeated 'base' facial identity (at 3, 6, 9, or 12Hz) periodically interspersed by novel 'oddball' identities (1 Hz). Base faces produce neural responses at their respective presentation rates, while oddballs—if discriminable—generate 1Hz discrimination-specific responses. Base-responses differed between groups, whereas oddball responses were equivalent, implying super-recognition is not identity discrimination-specific. Following similar methods, Experiment 2 isolated category discrimination-specific neuromarkers during periodic image sequences of naturalistic base objects (6Hz), interspersed by 1Hz face/house oddballs. Category-specific oddball-responses were greater to faces than houses in both groups, though super-recognizers showed greater base-responses overall. Thus, whatever the divergence between super-recognizers and controls, it stems from more general (non face-specific) perceptual processing. Experiment 3 considered whether this distinction arises from sensitivity to stimulus availability, or interstimulus temporal masking, by independently doubling base presentation rates (10 vs 20Hz) versus halving image durations (50 vs 100ms). Among the same base object and 1Hz face oddball images displayed in Experiment 2, only frequency doubling reduced oddball-responses (comparably between groups). Meanwhile, super-recognizers showed marginally greater oddball-responses across conditions, indicating that they may potentially experience reduced visual masking. Across experiments, subprocess-specific neuromarkers only weakly distinguish super-recognizers as a group. However, logistic classification and principal component analyses reveal individual-specific constellations of neurobehavioral data, suggesting super-recognizers are not all created equally. Overall, they are better identified by individualized neurobehavioral correlates.

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Yes, No, Maybe-so: An investigation of response option framing on face identification decisions

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Many situations rely on the accurate identification of people with whom we are unfamiliar. For example, security at airports or in police investigations require the identification of individuals from photo-ID. Yet, the identification of unfamiliar faces is error prone, even for practitioners who routinely perform this task. The challenge of unfamiliar face identification is often thought of as a perceptual problem. However, this assumption ignores the potential role of decision-making and its contributing factors (e.g., criterion placement). Across three experiments we investigated the influence of the framing of response options on sensitivity to identity (d') and criterion. In Experiment 1, participants (n = 90) completed an unfamiliar face matching task using one of three response options, comprising Same/Different, Same/Not-Same, and Same/Proceed-to-Next-Trial. In Experiment 2, participants (n = 189) completed the unfamiliar face matching task twice - once using the Same/Different response options (control condition) and then using one of the three response option types from Experiment 1 (experimental condition). In Experiment 3, participants (n = 208) completed the unfamiliar face matching task after being randomly assigned to one of two response options conditions (Same/Different, Same/Not-Same) and one of two base rate conditions (50% or 80% match trials). Across all three experiments, no effect of response options on face identification decisions was found —even after controlling for individual differences (Experiment 2) and despite clear effects of base rate (Experiment 3). These findings demonstrate that response framing and base rates exert separable influences on criterion placement despite carrying similar messages (e.g., that matches might be predominant), and point to complex and selective decision-making processes in face matching.

The perceptual integrality of sex and age: understanding the functional organisation of face processing

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Human faces convey complex and multidimensional visual information, and questions persist as to how information from different facial dimensions interacts in perceptual processing. This is the problem of perceptual integrality, research into which helps to elucidate the functional organisation of face processing. The current work takes a converging operations approach towards a deeper understanding of the visual integration between sex and age - a dyad of dimensions which is under-represented in the literature. We report a speeded classification task, a flanker task, two priming tasks and a task-switching task, each aimed at probing a different aspect of the potential interactions of sex and age. In general, the results of these experiments suggest that sex and age are asymmetrically integrated in human face processing - such that variations in irrelevant sex information affect age processing more than vice versa. We found evidence of this asymmetric integration at the level of sensory and semantic information - but not at the level of response selection. Furthermore, we found a robust Stroop-like effect in each experiment which revealed better performance in both sex and age processing when faces were either "young" and "female", or "old" and "male". We used three stimulus sets across these experiments and, in some cases, found that the direction or extent of effects changed as a function of the specific set of faces used. We argue that similarities and differences in experimental effects between sets may relate to the level of perceptual processing at which the respective effects occur. The implications of differences between sets for general social cognition experimentation are discussed. We argue that the asymmetrical integration of sex and age can be best described in terms of the complexity of processing necessary for the perception of each type of social information.

The neural basis of face pareidolia with human intracerebral recordings

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Even in highly recognizable stimuli, such as everyday living and non-living objects, the organization of certain features evokes the impression of viewing a face ('face pareidolia'). Objects eliciting this phenomenon are termed facelike-objects. Previous investigations employing neuroimaging techniques such as functional magnetic resonance imaging (fMRI), electroencephalography (EEG), and magnetoencephalography (MEG) consistently showed that faces and facelike-object images elicit responses in comparable ventral occipito-temporal (VOTC) regions, including the bilateral fusiform face area (FFA). However, the extent to which face pareidolia engages the same neural circuits as human faces remains unclear. Here, we address this question by directly measuring brain activity recorded from contact electrodes implanted in the VOTC of a large group of epileptic patients (n=44). We employed a frequency-tagging visual stimulation paradigm, previously validated in EEG, optimized to measure categorical selectivity for both faces and facelike-objects. Face-selectivity was determined by contrasting a large set of naturalistic face or facelike images with non-face stimuli depicting various living and non-living object categories. High signal-to-noise ratio face and facelike-object-selective responses were objectively identified and quantified throughout the VOTC. We observe selective activity for facelike-objects distributed across the human VOTC, from the occipital cortex (OCC) to the anterior temporal lobe (ATL), along the fusiform gyrus. While category-selective activity is markedly reduced for facelike objects compared to human faces (27%), consistent with previous findings, 89% of all facelike-object selective contacts spatially overlap with face-selective activations in regions thought to form a highly interconnected face-selective network. Furthermore, the two face-selective neural signals exhibit robust functional link, evidenced by their strong amplitude correlation across regions and recording contacts. Finally, their concurrent onset timing challenges the notion that facelike-objects are interpreted as faces through top-down processes. Together, our findings provide novel evidence supporting the view that face pareidolia engages the same neural circuits as human faces.

Evidence for an alternative account for the other-"race" effect, taking out "race"

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Learning experiments have shown opposite behavioural effects for other-race faces (learning costs) and caricatures of same-race faces (benefits). However, both face-types evoke similar patterns of event-related potentials (ERPs). We further investigated these seemingly paradoxical findings in a series of studies, hypothesising that they reflect qualitatively similar processes at learning for both face types, but with different consequences for recognition. Specifically, deviations from an observer´s perceptual norm enhance a face's distinctiveness and promote better representation and recognition of unfamiliar same-race (SR) faces – but both SR caricatures and other-race (OR) faces deviate from the norm although OR faces are hard to recognise. We hypothesize as critical difference that SR caricatures enhance individual distinctive information in each face, making it idiosyncratic and helpful for learning. In contrast, for OR faces, salient deviations affect "race" features – i.e., they tend to be unidirectional relative to the norm, and are therefore misleading. In three EEG experiments, we simulated an OR effect with highly distinctive same-race faces. In each experiment, we manipulated one particular characteristic in SR faces in a uniform direction (big noses, freckled skin texture, distinctive blue eyes). In a learning/recognition task, we compared performance and ERPs for these faces to veridical SR and OR faces. We found similar ERPs for OR and manipulated SR faces, accompanied by poorer recognition, compared to veridical SR faces. In a behavioural experiment, we could reverse the OR effect into an OR advantage, by increasing multidimensional distinctiveness in a set of OR faces, using ambient and diverse images from different ethnicities across the world. Overall, our results support a perceptual account of the OR effect rather than a social-cognitive account. We propose that qualitatively similar processes mediate the learning of unfamiliar SR and OR faces, but with different consequences that reflect differential usefulness of respective distinctive information.

Contextual Variability Does Not Improve Face Learning

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People recognize familiar faces with ease, but recognition of unfamiliar faces is error prone. Understanding how a newly encountered face becomes familiar is a critical next step for models of face recognition. A wealth of studies supports Vicki Bruce's contention that variability is key to learning. Images that capture changes in appearance from moment-to-moment (e.g., in expression and viewpoint) and day-to-day (e.g., in hairstyle, lighting, make-up, health) improve generalization of learning, such that novel images are recognized. This effect is thought to reflect a robust representation of an average and/or idiosyncratic variability in facial appearance. The aim of our study was to examine whether other, face-irrelevant, sources of variability also facilitate face learning. Raviv and colleagues recently identified four types of variability that influence learning across domains: numerosity (set size), heterogeneity of exemplars, contextual diversity, and scheduling. The latter two types have been largely ignored in studies of face recognition. Here, we examined whether contextual variability facilitates face learning while controlling for heterogeneity of face images. Evidence that contextual variability per se facilitates face learning would call for refinement of current models. In Experiment 1, participants (n=46) learned six identities. We manipulated heterogeneity of facial appearance (single-image; six low-variability images; six high-variability images) and the contextual diversity (single background; variable backgrounds) in which the faces were presented. Participants completed a recognition task in which novel images of the learned identity were intermixed with images of a similar distractor. In Experiment 2, participants (n=100) learned two identities from low-variability images; contextual diversity was manipulated. Across both studies, we found no evidence that contextual diversity increased sensitivity to identity (d') or shifted criteria (c), ps > .15. Our findings constrain which domain-general variability theories apply to face learning.
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Talk Session 7 - Material Perception

Viscosity or Roughness? – What makes a material unpleasant

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Touch provides discriminative and affective information about our environment. Many studies have shown how crucial discriminative touch is for gathering sensory information about materials, like their hardness or viscosity. In contrast, affective touch has attracted less attention, but is central to our daily lives. We base many decisions on affective material properties, like choosing a softer jumper instead of a hard and itchy one or avoiding touching or sitting on a slimy patch. The current study aims to identify materials that most people experience as being unpleasant to touch and to uncover the perceptual attributes that link to unpleasantness. To this end, we sampled 79 everyday materials covering a wide range of sensory properties. The materials were selected representing a diverse set of properties, such as fluid, granular, rough, and soft aspects, e.g., cooking oil, sand, coconut, and silk. We asked participants to freely explore these materials with their dominant hand and subsequently rate their unpleasantness and 23 sensory attributes (e.g., softness, stickiness) in the absence of visual and auditory feedback. We collected data on material unpleasantness from two countries: German and Scottish populations. Our wide array of materials showed different unpleasantness levels that correlated with specific perceptual material attributes. In general, viscous and rough materials (e.g., vaseline, coconut) felt more unpleasant to touch than deformable, granular, and fibrous materials. Results were comparable for the German and Scottish samples. Overall, our results revealed a relationship between specific sensory attributes of materials and their unpleasantness, which seems to be constant across different cultural backgrounds. These findings contribute to our understanding of how various tactile attributes are related to unpleasantness. This has implications for product design by informing design choices.
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Multisensory saliency in object surface exploration

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In active exploration, we focus on salient parts of objects. Research extensively covers visual saliency, yet haptic and multisensory saliency remain less explored. We investigated how haptic and visual saliency interact in object surface perception. Twelve participants explored 60 stimuli, whose surface relief varied locally, under three different conditions: vision-only, touch-only and with both together (multisensory). We used eye tracking glasses (SMI) to record eye-movements and record the video of the exploration of the first stimulus. We used marker-less tracking software (Deeplabcut) to extract the position of the index finger in each frame of the video, as our previous research has shown that it is most predictive of haptic bottom-up saliency. Additionally, we extracted the position of four landmarks, marking the corners of the stimulus in order to map eye and hand movements onto the stimulus surface. The correlation between fixation and touch density maps was significantly stronger in the multisensory condition (r=0.28) compared to the vision-only and touch-only conditions (r=0.03); t(10)=4.4997, p=0.0011. This suggests that touch and vision mutually influence each other, as exploratory movements are more similar when occurring simultaneously. Furthermore, regressions analyses showed that touch-only saliency contributes to predicting multisensory visual saliency, and vision-only saliency contributes to predicting multisensory touch saliency, despite vision-only and touch-only density maps are nearly orthogonal (r=0.03). This indicates that in the multisensory condition both tactile and visual exploration share properties with exploration done with the other sense only. Haptic saliency in the multisensory condition is a better predictor for visual saliency than haptic saliency in the touch-only condition. However, visual saliency in the multisensory condition does not predict haptic saliency better than visual saliency in the vision-only condition. This suggests that in the multisensory condition touch follows vision while vision is more independent, however dynamic interactions will be discussed.
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Relative Contribution of Boundary Motion in Material Perception

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Motion is an important cue in the perception of optical and mechanical qualities of materials. Dynamic dot stimuli have been used in previous research to demonstrate that observers can estimate mechanical properties of non-rigid materials based on motion information alone. Motion information in these stimuli stems from both, interior object -, and object boundary motion. However, what the relative contribution of each of these motion cues to the perception of material qualities is, is unknown. To address this, we measured how human observers perceive material qualities from animations of full textured stimuli, that have all optical and motion information (‘full’), dynamic dot stimuli (‘dots’), and dynamic line drawings (‘lines’). Unlike ‘dots’, ‘lines’ depict only boundary information (for sample stimuli, see https://jlubox.uni-giessen.de/getlink/fi9xJ5W9kN1drXPBodkz1HCY/). We rendered the three versions (full, dots, lines) of material animations from five material categories (fabrics, hard breakables, jelly, liquids, smoke), and performed two experiments: a rating experiment where observers rated five material attributes (dense, flexible, wobbly, fluid, airy motion) and a triple AFC experiment where observers were asked to choose one of the two materials, which is more similar to third material across all possible combinations. Comparisons of similarity analyses from both experiments across the three rendering conditions show that ‘lines’ also convey material properties convincingly. We conclude that boundary motion might play a critical role in the perception of mechanical material qualities.

Sound symbolic characteristics of natural materials

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Material perception research has been focusing on visual and haptic modalities with fewer examples of auditory stimuli. To bridge the gap, we present data relating to the linguistic counterparts of perceived material characteristics. Sound symbolism in linguistics provides examples, such as words that imitate the sounds of natural materials they describe (onomatopoeic words, e.g., crunch or splash). We

have previously shown that spoken onomatopoeic words yield similar perceptual dimensions as visual and haptic materials and have dimension-specific effects on perceived visual softness. Here, we aim to measure the level of mimicry in the sound symbolic (SS) relationships between Turkish onomatopoeic words and natural materials. We use visual and haptic materials, natural sound effects, and written names of material categories to extract phonetic characteristics associated with each type of stimulus. We first collected SS words associated with 178 written material names (n=85). In a separate study, we presented 60 natural sound effects and asked participants (n=34) to write down what they heard. Finally, two separate groups of participants (n=26 and 14) were asked to come up with pseudo-SS words while 1) watching material videos and 2) touching objects. After analyzing the phonetic characteristics, we find distinctive SS relationships, such as Turkish ş [ʃ] sound for fine granular and viscous materials, ç [tʃ] sound for coarse granular materials, and c [dʒ] sound for sticky materials. Similarity matrices for each modality revealed that SS words 1) have unique associations with previously defined perceived softness dimensions such as granularity and fluidity, 2) bring out a novel dimension (airiness) different from reported visual/haptic findings, 3) follow mechanical properties rather than material categories (e.g., shaking rice and sugar being higher correlated than shaking and pouring sugar), and 4) reveal similar distinctive sound patterns for audio, visual, and haptic stimuli.

Precision Grip and Unconstrained Visually-Guided Grasping of Multi-Material Objects

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Previous research on visually-guided grasping largely focuses on precision grip, partly because precision grip is easier to measure and model. However, in daily life we rarely pick up objects using just two fingers. Do findings based on precision grip generalize to unconstrained grasping? To test this, we employed a subset of 3D multi-material objects from a published precision grip study. Stimuli were four objects, each one made of five contiguous cubes of wood and five contiguous cubes of brass (cube side length 2.5 cm, object mass 716 g). Cubes were connected into two shapes and two material configurations, such that the heavy brass side was the nearest or farthest portions of an object to the actor. Twenty participants grasped these objects in two different sessions while we tracked full hand and object movements using a Qualisys passive marker motion capture system. In an unconstrained grasping session participants could grasp the objects however they wanted. In a “precision grip” session participants were required to use only thumb and index finger. We found that in the unconstrained session participants rarely employed precision grips ($p<.001$). Nevertheless, in both precision and unconstrained sessions, participants shifted their grasps towards the objects’ centre of mass to minimize grip torque ($p=.017$). Further, in unconstrained sessions participants selected similar contact locations for thumb and index fingers as in precision grip sessions, with the key difference that they used the remaining fingers to stabilize and secure their grasps. Our findings thus corroborate the impact of material appearance on visual grasp selection. To further this work, we have now integrated our motion capture system with a VR headset. In this way, we can map onto the physical objects different virtual appearances, allowing us to explore how the visuomotor system responds to discrepancies between physical and virtual object properties.

The Contribution of Auditory and Haptic Target Information in Guiding Reaching Movements

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In everyday life, we separately or jointly use auditory and haptic inputs to define a target position and guide our movements toward it (i.e., catching a fly that landed on our arm). However, how we use haptic, auditory, and audio-haptic target information to guide our actions is yet unknown. Here, we investigated this question by asking 25 blindfolded participants to perform right-hand reaching movements toward haptic (H, left index finger), auditory (A, speaker emitting pink noise), or audio-haptic (AH) targets positioned underneath a panel, 35 cm in front (0 deg) or to the left (45 deg, and 90 deg) from a starting position. By modeling the endpoint error in azimuth and depth through a Bayesian distributional regression model, we found an overall undershooting across directions, with credibly lower precision in A compared to H and AH, and a credibly similar precision between H and AH. Sensory combination in AH was investigated by combining unisensory reliabilities through three different sensory integration models (Weighted Linear Cue Combination, Maximum Likelihood, and Probabilistic Cue Switch), and directly comparing the models’ predictions with the multisensory reliability. The Weighted Linear Cue Combination model best predicted the action performance in the multisensory condition. Sensory inputs were linearly combined and slightly correlated (0.1), with a higher weight for haptic than auditory target information. A second experiment (n = 25) revealed that audio-haptic training minimally impacts auditory target reaching precision, with no improvement in precision across trials. Overall, results indicate the existence of two independent processes for action guidance toward auditory and haptic targets, with haptics predominating in multisensory conditions. The lack of a multisensory training advantage suggests that the improvement in auditory localization usually seen following multisensory training may stem from factors other than a multisensory integration of target-related positional information.

Talk Session 8 - 3D Vision, Depth & Stereo

Can we reshape depth cue integration? Evidence of perceptual cue reweighting through dynamic interaction experience

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Accurate estimations of object properties in 3D environments derive from effective combination of available visual depth cues, even when conflictual. Previous research showed that depth cue weighting is influenced by manipulation of the reafferent signal by complementary sensory modalities, e.g. haptics. These action-perception loops contribute to the development of sensorimotor abilities by inducing perceptual learning and adaptation. We demonstrated that dynamic interaction with conflicting stimuli could induce changes in cue combination mechanism, even without feedback. We explore how interaction affects cue weighting by developing a novel

experimental approach exploiting Unity3D and VR technology. We create 3D oriented (slant and tilt) surfaces with consistent and conflicting texture and binocular disparity cues, allowing contingent adjustments of perceptual parameters with participants' actions. Participants undergo an initial perceptual matching task, where they are asked to adjust through the HTC Vive controller touchpad, the orientation of a consistent stimulus to match the orientation of a conflicting test stimulus. This is followed by a training phase, after which the task is repeated. During contextual active texture and disparity (ATD) training, participants are instructed to continuously move by a joystick a conflictual 3D surface to align the perceive depth gradient along diametrically opposing target tilts. The interactive experience lasts 40s. We add a random tilt to decouple subject's movements from visual stimulus' movement. Control groups (active texture - AT, active disparity - AD) interact with only one cue, while the other remains fixed. Results show a pre- vs. post- cue reweighting in favor of texture for ATD, whereas no changes for AT and AD, although a contingent cue dominance is observed during training. We suggest that experiencing dynamic cue combination is crucial to induce perceptual cue reweighting. Control group results demonstrate that the reinforcement is not merely due to the experience of an additional motion cue.

The importance of measuring coarse stereopsis in the assessment of residual binocular function

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Stereoscopic depth perception may be obtained from small retinal disparities that can be fused for single vision (fine stereopsis), but reliable depth information is also obtained from larger disparities that produce double vision (coarse stereopsis). We have shown previously that coarse stereopsis typically matures earlier than fine stereopsis and can be spared in amblyopia even when fine stereopsis is disrupted. Moreover, coarse stereopsis facilitates eye alignment and the subsequent development of fine stereopsis following strabismus surgery. We further explored the role of coarse stereopsis in visual development by examining the relationship between the etiology of amblyopia and stereoscopic depth perception over a wide range of disparities from fine to coarse. Accuracy on a depth discrimination task was assessed in 90 children with binocular vision disorder (anisometropic, aniso-strabismic, or strabismic amblyopia; or strabismus without amblyopia), and 90 age-similar controls. On each trial, participants viewed a dichoptically-presented cartoon character with crossed or uncrossed disparity and reported the depth sign (near/far) relative to a zero-disparity reference frame. Stimuli were adjusted to correct eye misalignment. We tested 6 disparities characterized either as fine (0.02, 0.17, 0.67 degrees) or coarse (2.0, 2.5, 3.0 degrees) based on measurement of diplopia thresholds. In the fine range, all four patient groups performed worse than controls, and discrimination accuracy was correlated with stereoacuity measured with the Randot Preschool Stereotest. In the coarse range, however, all three amblyopia groups performed similarly to controls, and there was no correlation between discrimination accuracy and stereoacuity. Our results show that conventional clinical measures that test only disparities in the fusional range may miss stereopsis in amblyopia. This undetected residual binocular function has important clinical implications given recent efforts to improve amblyopia treatment outcomes by employing binocular treatment protocols.
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Depth perception from disparity, motion parallax and their combination in patients with central field loss

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In a normally sighted viewer, each retina captures a slightly different image of the world, referred to as disparity, which provides depth information. In individuals with central field loss, this binocular depth information is impacted in regions of the visual field where there is vision loss in either eye. However, depth information can also be extracted using monocular cues like motion parallax. This study aims to determine if combining disparity and motion parallax can improve depth perception and compensate for the loss of fine binocular depth cues when foveal vision is lost. Thirteen controls viewed stimuli consisting of random dots made up a sine wave profile in depth, defined by disparity and/or motion parallax. Participants had to report which half cycle appeared farther away from the fixation cross. We measured thresholds for disparity and motion parallax alone, as well as for their combination, i.e., we measured thresholds for motion parallax added to the threshold disparity value, and vice versa. These thresholds were assessed with foveal vision and with simulated scotomata of 4°, 6° and 8° diameter. Results show significantly reduced thresholds when disparity and motion parallax were combined, even in the presence of a scotoma. With the addition of motion parallax, disparity thresholds decreased by 46.06 ± 7.48% and by 23.27 ± 16.38%, without and with an 8° scotoma. With the addition of disparity, motion parallax thresholds decreased by 80.90 ± 18.82% and by 68.88 ± 7.72% without and with an 8°scotoma ($p < 0.001$). Similar improvements were observed in 4 macular degeneration patients (mean improvement = 13.11 ± 15.75% for disparity and 51.32 ± 26.74% for motion parallax). Our results suggest that peripheral disparity and motion parallax together can enhance depth perception in patients with central field loss.
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Dual-task costs suggest dependence between depth and 3D curvature processing

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Multitasking theory suggests that the ability to execute two tasks simultaneously depends on the amount of representation sharing between the two tasks, with greater representation sharing leading to greater processing interference and, thereby, greater dual-task costs. In this study, we leverage the dual-task paradigm to probe the representational overlap between two 3D shape properties—depth and curvature. Observers were asked to report which of two stereoscopically presented 3D bumps was deeper (depth task), or which was more bell-like (curvature task). Critically, on each trial the observers needed to process both tasks simultaneously (dual-task) since the relevant task was not revealed until after the stimulus presentation. If depth and curvature processing relies on a shared representation, the dual-task costs of independently judging these two properties would be greater than the dual-task costs of independently judging depth and distance, a property unrelated to 3D shape that is expected to rely on a separate representation.

Conversely, if depth and curvature are represented separately, there should be no difference in dual-task costs between the multitasking settings and thus no change to the depth discrimination threshold. We carefully calibrated a stimulus set that was used across all tasks, where the curvature and distance levels were calibrated for each observer to ensure that the two tasks had the same difficulty. Observers completed a single-task session (depth task only) and two dual-task sessions (depth-and-curvature or depth-and-distance). We assessed dual-task costs as the relative change in depth discrimination thresholds between a single-task session and the two dual-task sessions. Strikingly, we found that the increase in depth discrimination threshold for the depth-and-curvature dual-task session compared to the single-task session was significantly greater than the increase in depth-and-distance session. This suggests a greater dependence in the encoding of depth and curvature compared to shape-irrelevant distance estimate.
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All sizes of the Moon - perceived size and depth cues distribution

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According to the flattened sky dome hypothesis, the Moon illusion appears due to numerous depth-cues toward the horizon and little of them toward the zenith. Besides that, their spatial distribution changes, since towards the horizon numerous depth-cues appear only near the observer, while toward the zenith, the lack of depth-cues is similar all the way. To examine this alternative hypothesis, we performed two experiments. In the first experiment, 19 participants matched sizes of two spheres (0.2m or 0.4m), positioned left and right from the observer on 2m or 20m, in a virtual reality display (Oculus-Rift). There were three depth-cues distribution situations: 1) dark space; 2) space filled with depth-cues all the way; and 3) space filled only close to the observer. Participants matched a sphere in empty space with a sphere in other two situations. Results showed statistically significant differences between empty and half-filled space (η^2=.44) and empty and space filled all the way (η^2=.26). In both comparisons participants perceived a sphere as larger if depth-cues were present. Still, effect sizes indicate that differences were larger for comparison of an empty with half-filled space. Since on 20m distance stimulus was hardly visible, we performed a second experiment, with stimuli on a 2m and 10m distance, and 21 participants comparing all three situations. Again, results showed statistically significant differences between empty and half-filled space (η^2=.73), empty and space filled all the way (η^2=.68), and half-filled and space filled all the way (η^2=.63). Although results show a similar pattern, the largest difference between empty and half-filled space, on the other hand, sphere was perceived as larger if the space was filled all the way than if it was half-filled. Results are in line with the flattened sky dome hypothesis, but also partially with our alternative hypothesis for the Moon illusion explanation.

Treating adult amblyopia through combined physical exercise and inverse occlusion: evidence from 7T BOLD responses

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While amblyopia can be ameliorated in children, treating it in adults is challenging. Among the new therapeutic approaches, combining physical exercise with short-term occlusion of the weaker eye has shown promise in improving visual acuity. Here, we tested the effects of such combined treatment on visual evoked responses in the primary visual cortex (V1) measured with ultra-high field fMRI. We studied eight amblyopic adults (aged between 16 and 44 years old), with amblyopia caused by anisometropia or infant strabismus. After a detailed ophthalmic examination, they underwent fMRI scanning at 7T. BOLD responses to five band-pass-noise monocular visual stimuli (peak spatial frequency ranging from 0.1 to 2.7 cpd), were measured before and after 2 hours of covering the amblyopic eye with a translucent patch. We repeated this protocol after a 4 week training performed at home, in telemedicine. The training was composed of six sessions (three in the first week and one in each of the following weeks) where the 2 hour patching was combined with cycling on a stationary bike. In line with our previous findings, the training improved amblyopic eye acuity by 0.10 ± 0.05 logMAR (as measured with an automated Tumbling E test). 7T BOLD responses in V1 to higher spatial frequencies were reduced for the amblyopic eye compared to the fellow eye. This dominance of the fellow eye responses decreased after the 2 hour patching and after the 4 week training. Using binocular rivalry we indexed ocular dominance and observed a reduction of the fellow eye dominance after patching and further after the 4 week training. In conclusion, treating amblyopic adults with a combination of physical exercise and short-term inverse occlusion produced a shift of ocular dominance, measured behaviorally and with 7TfMRI, and revealed a reorganization of V1-evoked responses favoring the amblyopic eye.
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Wednesday 28th August

Poster Session 5

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Retention of non-configural face information

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In order to identify faces, the perceptual information is matched against face representations stored in memory. As configural face information, especially so-called 2nd-order relations, are believed to be essential for facial identification processes, we can assume that configural information is an important part of mental face representations. This might be the reason for research having focused on configural aspects in the past. Non-configural face information (e.g., color information) has received less consideration so its role in recognizing and memorizing is much unclearer. Face adaptation serves as an ideal tool to investigate whether specific face information is part of face representation. In a series of several experiments, we could reveal that face representations indeed seem to contain non-configural information as well. However, results indicate a different quality of retention. While configural changes in faces cause extremely long-lasting alterations in face representation, non-configural changes seem to induce less robust adaptation effects. We believe that face information is represented based on its variability in natural contexts. Following this assumption, in everyday life highly variable types of information, such as non-configural color information (e.g., brightness or saturation), would only evoke transient changes in face representation, while more stable face information, such as face configurations, lead to longer-lasting adjustments.
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Impact of PTSD on attentional capture, guidance, and target verification during visual search

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Control of attention and inhibition is impacted in post-traumatic stress disorder (PTSD). This is likely to affect the proactive control of eye movements and the suppression of irrelevant distractors during visual search. In the present study, we use the irrelevant singleton paradigm to investigate the efficiency of search in the presence and absence of an irrelevant distractor in a sample of UK service veterans with varying severity of PTSD. Participants were required to discriminate the orientation of a target centred in a shape singleton in displays containing circles and triangles. On 50% of trials, one of the distractors was replaced by a salient colour singleton of the same shape, which participants were told to ignore. Displays contained 8 objects presented on a virtual circle at an eccentricity of 7.35˚. Manual and saccadic indices of performance were used to quantify attentional capture and the speed and efficiency of search in the presence and absence of the irrelevant colour singleton. Initial results reveal comparable reaction times (RTs) but an increase in the latency of the first target fixation in the presence of the irrelevant colour singleton, indicating attentional capture during visual sampling. Higher PTSD symptom severity was associated with a general increase in RTs, the number of fixations, and verification time (time between the first target fixation and response). Variability across manual and saccadic indices also increased as a function of PTSD symptom severity. These data support a decrease in the inhibition of the irrelevant singleton during visual sampling in individuals with PTSD. Increases in PTSD severity are also associated with a decrease in the speed and selectivity of visual sampling during search. These findings support a reduction in the efficacy of attentional mechanisms that mediate the proactive control of selective attention during the guidance and verification stages of visual search.
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Testing the interaction between fine and coarse scales with moving plaids

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An interaction between fine and coarse spatial scales occurs during motion processing. In this study, we wanted to determine the role of MT visual cortical area on this motion mechanism. We conducted two experiments using moving plaids of different spatial frequencies windowed by a 2D Gaussian function of different sizes, since MT visual area contains neurons that process the pattern motion direction of this kind of stimuli. We measured the proportion of correct responses for 4 durations (25, 50, 100, and 200 ms). In the first experiment, we tested 3 sizes (0.7, 2, and 4 deg), and different spatial frequency combinations (1m, 3m, 1s+3m, 1m+3s, 1m+3m, where m stands for moving and s for static). The moving components drifted at 4 deg/s. Results showed that the interaction between spatial frequencies depends on the components combined, on the size of the plaid, and on its duration on the screen. It strongly arises for 1s+3m and large sizes, and it's not present for the smallest size. Given than MT neurons show a non-homogeneity of the antagonistic surround, in the second experiment, we tested the effect of the window shape on the interaction between spatial scales. We tested two oval windows, one vertical (Sx=0.35, Sy=1.4 deg) and one horizontal (Sx=1.4, Sy=0.35 deg) using plaids with the same durations, drifting speed, and the complex spatial-frequency combinations from the previous experiment. Results revealed that the interaction between spatial scales only occurs, for the condition 1s+3m, when the window is elongated in the direction of motion, and intensifies as duration decreases. These findings suggest that MT visual cortical area is a plausible origin of the interaction between spatial scales in motion perception and show that the activity of this motion mechanism depends on the size, shape, and duration of the stimulus.
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Age-Related Visual Search: Distractor Impact on Reaction Times and Accuracy

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Visual processing speed and inhibitory control are critical cognitive abilities that influence our ability to navigate complex visual environments. However, these abilities are known to decline with age, potentially leading to difficulties in tasks that require efficient processing of relevant information while suppressing distracting stimuli. This study investigated the effects of age, target presence, and distractor interference on visual search performance using a novel experimental paradigm that systematically manipulated these factors. Younger and older adults completed a series of visual search trials, where they had to indicate the presence or absence of a target

stimulus within displays containing varying distractors. Reaction times and accuracy were recorded, providing insights into the efficiency of visual processing and inhibitory control mechanisms. The results revealed significant age-related differences in reaction times and accuracy, with older adults exhibiting longer response times and reduced accuracy than their younger counterparts. Moreover, increasing distractor levels led to a more pronounced decline in performance for older adults, particularly when the target was present. The ANOVA analyses revealed significant main effects of age, target presence, distractor level, and intricate interactions between these factors. These findings highlight the critical role of inhibitory control in inefficient visual processing and suggest that age-related declines in this cognitive function may contribute to the observed performance differences between younger and older adults in visually complex environments. The study has important implications for understanding age-related changes in visual attention and perception and informing the design of user interfaces and visual displays that account for the unique needs of older individuals.

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Investigating semantic properties of objects in scenes using fine-grained crowd-sourced and computational methods

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For most man-made environments, it is straightforward to tell what objects are likely to appear in them and what are not. In the studies investigating the effects of these regularities on human perception, these objects are referred to as, respectively, semantically consistent and inconsistent with a given scene context. While this distinction is useful, its dichotomous nature hampers the investigation of the effects of graded object-context consistency (e.g. a wristwatch and a kettle might be consistent with the context of a kitchen table to different degrees). There are several ways to quantify the semantic consistency in a continuous (and not dichotomous) fashion and thereby overcome this limitation. Here, we tested them. Participants viewed scenes with objects that were – according to previous studies – either semantically consistent or inconsistent with these scenes and rated on a six-point scale either the semantic consistency of these objects or the frequency with which they appear in the given contexts. In one experiment, a single group viewed scenes with both consistent and inconsistent objects while in the other, different groups viewed scenes of these two types. We found that although raters in the first experiment tended to select more extreme points from the scale than in the second, the frequency and consistency ratings were always highly correlated (~0.8). Next, we tested if human ratings can be emulated using a pipeline in which GloVe – a computational model capturing semantic relationships between words – processes the names of objects in scenes. The highest correlation between the model consistency scores and the human data amounted to 0.39. We conclude that although the way in which semantic consistency is measured in rating studies affects their outcome, people largely agree regarding how they judge object-scene relationships. Developing computational methods that would emulate these judgements, however, remains challenging.
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Objects, Faces and Words Processing in Dyslexic and Typical Readers: Steady-State Visual Evoked Potentials Study

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Developmental dyslexia is a learning disorder commonly associated with atypical phonological processing, and the visual part of the reading process is often left behind. At the same time, vision is an essential part of word recognition, and individual differences in visual processing can potentially predict reading abilities. Our hypothesis on high-level visual dysfunction suggests that reading difficulties experienced by certain individuals with dyslexia can indicate a broader impairment in visual cognition. The study employed steady-state visual-evoked potentials (SSVEPs) to investigate visual processing in dyslexic and typical adult readers, leveraging the method's high signal-to-noise ratio for robust data collection (total N = 62). The research involved three preregistered tasks (https://osf.io/4dr3f) — focusing on faces, objects, and text/pseudofonts— using a fast periodic oddball paradigm where stimuli (e.g., face A) were presented at a base frequency of 6 Hz with oddball stimuli (e.g., face B) interspersed at a rate of 1.2 Hz (AAAABAAAABAA…). Our research highlights differences in face and object processing, where dyslexic participants exhibited higher base frequency power in the right hemisphere compared to typical readers when attending and memorizing faces and objects, and higher oddball frequency power when attending and memorizing objects. Contrary to our expectations, the text paradigm revealed no significant differences in base or oddball frequency power between dyslexic and typically reading participants. We speculate that this is due to the passive nature of this task, which unlike tasks for faces and objects did not require participants to attend to and memorize the SSVEP stimuli. These findings may suggest that some individuals with developmental dyslexia require additional neural resources to recognize and discriminate faces and objects.
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Are our representations of familiar faces weighted towards our most recent encounters?

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People can recognise the faces of friends and family across substantial age-related changes in appearance (e.g., in old family photographs and at a recent family gathering). However, little is known about how familiar faces known for many years are represented. One possibility is that our representations are weighted towards our most recent encounters with a familiar face. Here, we investigated this using averages (created by morphing multiple images of the same person together) and instances of characters from the popular and longstanding UK TV soap opera Coronation Street. Ninety-four participants who regularly watched Coronation Street for at least the last 20 years completed both a likeness task and a speeded name verification task in which they were presented with face averages and

instances. The stimuli used in both tasks were the faces of Coronation Street characters who had been on the show continuously for at least the last 20 years. For each character there were three face averages (past weighted, non-weighted, recent weighed) and three instances (past instance, mid instance, recent instance). On the likeness task, recently taken instances and recent-weighted averages were rated as a better likeness than non-weighted averages/mid instances and early weighted averages/instances. On the speeded name verification task, recent instances/recently weighted averages and mid instances/non-weighted averages were recognised faster than the past instances/past-weighted averages, but there was no difference between the mid instances/non-weighted averages and the recent instances/recent weighted averages. These results have implications for the nature of longstanding representations of familiar faces and suggest that our representations may be updated by experience with more weight given to more recent encounters with a familiar person.
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Visual search and stimulus similarity: An empirical study with real images and convolutional neural networks

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The ability to predict how efficiently a person finds an object in the environment is a crucial goal of attention research. Drawing on a broad range of findings, the literature has identified two main factors that impact search efficiency. The first factor is the similarity between targets and distractors (target-distractor similarity), where an increase results in a decrease in search efficiency. The second is the similarity among distractors (distractor-distractor similarity), where an increase, conversely, leads to an improvement in efficiency. However, the validity of these similarity principles has so far been established using a limited range of essential stimulus materials under highly restrictive conditions (such as letters, colour patches, or single lines, varying in a limited number of attributes) and lacks direct quantitative support with more ecologically valid real-world stimuli. This study exploits convolutional neural networks to predict human search efficiency from computational estimates of similarity between real-world object images. Our results provide ecological evidence supporting the similarity principles in visual search: search efficiency varies across tasks and conditions and improves with decreasing target-distractor similarity and increasing distractor-distractor similarity. Furthermore, our results reveal a crucial dissociation: target-distractor and distractor-distractor similarities mainly operate at two distinct layers of the network; distractor-distractor similarity at the intermediate layers of coarse object features, while target-distractor similarity at the final layers of complex features used for classification. This suggests that these different similarities exert their major effects at two distinct perceptual levels and demonstrates our methodology's potential to offer insights into the depth of visual processing on which the search relies. By integrating computational techniques with principles of visual search, this approach aligns with contemporary trends in other research areas and meets longstanding demands for more ecologically valid research in the field of visual search.

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Reducing the Perceptibility of Phase Shifts in Sequences of Visual Stimuli

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Sequences of alternating visual stimuli are typically perceived as flickering. In Neuroscience this method is widely used to elicit Steady State Visually Evoked Potentials and for certain coding schemes in Brain-Computer Interfaces. Because flicker is unpleasant, it might be reduced by alternating the stimuli at frequencies above the flicker-fusion threshold. For example, rapidly alternating black and white stimuli would then be perceived as constant gray. Nevertheless, shifts between phases remain discernible. For example, when switching from a black-white sequence to a white-black sequence, the direct repetition of the white stimulus is perceived as a flash. Reducing the perceptibility of phase shifts could allow for new coding schemes in Brain-Computer Interfaces. We therefore investigated different methods to minimize the perceptibility of phase shifts for black-white flicker stimuli. We used three types of phase shifts: (a) gradient-based (gradually reducing the black and white stimuli to the perceived mid-gray level and then back to full contrast at the shifted phase), (b) high-pass and band-pass filtered shifts (applying filters to smooth out the shifts), and (c) flipping pixels (changing sequentially single pixels from one phase to another). In a two-alternative forced choice task, participants (N=24) discriminated intervals with and without phase shifts. Discrimination performance was worst for the gradient-based phase shifts with percent correct of 66.1% +/- 2.8 and 68.5% +/- 3.1 for Kaiser and Tukey gradients, respectively (mean +/- standard error of the mean). These phase shifts are therefore promising candidates for future applications in Brain-Computer Interface coding schemes.
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Trial sequences are not effective cues for contextual saccadic adaptation

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Contextual saccadic adaptation is elicited using a variant of McLaughlin's double-step paradigm, in which two distinct cues signal the direction of the intrasaccadic steps. This allows for the induction of two simultaneous saccadic adaptations. Remarkably, research has shown that effective contextual adaptation occurs with motor command-related cues, e.g. the initial step direction or head orientation, but not with visual cues, e.g. the target color or shape. We further explored this phenomenon by probing the effectiveness of statistical regularities across trials. Participants were instructed to saccade toward a target that stepped obliquely after an initial fixation period. During the saccade, the target stepped again, this time orthogonally to the first step. This intrasaccadic step (ISS) could be either upward and leftward, or downward and rightward. Across three experiments (n=30) the possible ISS directions followed fixed sequences across

trials: the two ISS were either 1) alternating from one trial to the next, 2) organized in short blocks of four consecutive trials, or 3) in longer blocks of ten consecutive trials. In a control experiment (n=10), we used the first step amplitude as a context: short (5deg) and long (10deg) first target steps were each paired with one of the two ISS directions. We observed robust systematic contextual learning under the first step amplitude condition. However, there was no learning in the three trial sequence-defined conditions. These results further validate the idea that effective prediction of the intrasaccadic step strongly depends on the nature of the context. Specifically, our results are consistent with the notion that motor cues, as opposed to purely perceptual cues, are necessary for contextual motor adaptation: effective contexts are readily associated with specific motor states.
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Investigating the warping of spatial experience across the blind spot to contrast accounts of consciousness

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This work is done in the context of an adversarial collaboration to test contrasting predictions of the Integrated Information Theory and Predictive Processing (PP) accounts of consciousness. We investigate conscious experience of space around the visual blind spot area. Compared to other regions of our visual field which rely on feedforward information from the lateral geniculate nucleus, the cortical representation of the blind spot exploits its lateral and feedback connectivity for filling in processes. According to the Integrated Information Theory of consciousness, non-activated regions between stimuli and non-activatable regions in the blind-spot contribute differently to the perceived quality of space as the retinotopic cortex creates a different cause-effect structure inside and outside the blindspot. Predictive Processing accounts, in contrast, posit that internal models will accommodate structural deviations around the blindspot.PP-Neurorepresentationalism predicts no spatial disruptions if the underlying mechanism utilises around-blindspot neuronal compartments, and modest distortions if they don't. PP-Active Inference predicts no bias but differences in the precision of judgements as the sampling becomes affected around the blindspot. We present a paradigm in which participants compare the distances between pairs of dots that span or do not span the blind spot (importantly, all stimulation is done outside of the blind spot area to avoid filling in effects). We use coloured glasses for eye-specific stimulation. With this data, we model psychometric functions relating perceived and objective distance. These models vary in terms of bias and precision according to the experimental conditions (around vs. not around the blind spot, ipsilateral vs. contralateral eye), making it possible to quantify the potential disruption of distance perception induced by the blind spot in the ipsilateral eye. To illustrate the sensitivity of our paradigm, we present a control dataset considering trials during which the blind spot was not involved.
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A multiscale model of alpha traveling waves in the visual system

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There is abundant evidence that low-frequency oscillations in the cortex are often spatially organized as traveling waves. The occurrence of these waves, as well as their dynamical properties, have been linked to various perceptual and cognitive measures. In the EEG, the direction of alpha-band traveling waves is bimodal, with peaks in both directions on the occipito-frontal axis. These two wave directions are associated with distinct functional roles: forward waves are most prominent during visual processing, while backward waves dominate at rest and during suppression of visual input. Previous modeling work showed that recurrent feedback in a predictive coding framework can explain these dynamics; however, a biologically plausible model is still lacking. Here, we present a hierarchical, multiscale network with mean-field dynamics that, starting from the laminar connections in the cortex, reproduces the behavior of alpha-band traveling waves as observed in the EEG signals. Following known anatomical connectivity, we show that forward and backward waves are likely generated in separate sub-networks connected in infragranular layers at each area. This architecture creates a competition between the two states biased by incoming signals from either direction (bottom-up/top-down, simulating incoming sensory information and internal priors, respectively). In a second step, we extend our model to include the cortico-thalamo-cortical pathway through the Pulvinar. The Pulvinar is a higher-order visual thalamic nucleus involved in generating alpha-band oscillations, that mediates a second, redundant connection for any two visual areas connected cortically. We show that this pathway can modulate the cortex's competition between forward and backward waves. Our simulations suggest a key role for the Pulvinar in directing information flow in the cortex, in line with previous studies. In summary, our model provides a biologically plausible multiscale architecture to explain the dynamics of macroscale traveling waves and relate EEG results to distinct components of the thalamo-cortical circuitry.
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Visual Perceptual Learning of a Crowding Task: Effects of ageing

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Visual crowding refers to the detrimental effect of flanking distractors on the recognition of peripherally presented objects. Crowding is characterized by a radial-tangential anisotropy, which describes an ellipsoid shape of the crowding area elongated along the radial fovea-target axis. The critical distance between target and flankers, where crowding begins to significantly impair target recognition, can be

reduced by perceptual learning. In this experiment we investigated the learning-induced reduction of crowding in normally-sighted participants across three age groups (20-40 years, N=30; 40-60 years, N=21; 60-80 years, N=14), who were trained over four sessions to detect the Landolt-C gap orientation (4AFC; up, down, left or right) flanked by same-sized ring distractors in the upper left and right visual quadrants (6.5° eccentric of central fixation). A staircase procedure adjusted the critical target-to-flanker distance needed to achieve 70.7% correct responses during training. The results indicate that all three age groups improved significantly over four sessions ($p < .001$), exhibiting a reduction in the critical target-to-flanker distance. The main effect of age was not significant. Interestingly, the radial-tangential anisotropy of crowding was less pronounced in the two older age groups in comparison to the youngest group and it tended to decrease with training. The results suggest that perceptual learning of a crowding task is also feasible for midlife and elderly participants. As such perceptual learning could be a promising tool in rehabilitation to improve eccentric vision in young and old patients with central vision loss.
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Reduced responsibility for task performance: social judgments when drawing in automated environments

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In recent years, the implementation of information technology that automatically intervenes in human sensory and motor functions, such as autonomous driving vehicles, has expanded rapidly. It is expected that in the near future, societal interactions involving individuals whose abilities have been enhanced by such automation technology will become commonplace. This study investigated the effects of interventions in sensory and motor functions by automation technology on social judgments in social interaction contexts. In the experiments, participants performed competitive or non-competitive tasks with avatars controlled by programmed algorithms displayed on a monitor. We investigated how differences in the performance of the avatars, used by the participants themselves or by others, affected participants' evaluations of their own task performance (how well they felt they had done and how much responsibility they felt for the outcome). The results showed that in competitive scenarios, when the performance of avatars used by themselves and others was equal, the sense of responsibility for the outcome was higher than in non-competitive scenarios, whereas when there were differences in avatar performance, the sense of responsibility for the outcome was lower. These findings suggest that in social interaction contexts involving individuals whose capabilities have been enhanced by automation technology, differences in capabilities may influence individual social judgments.
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Postural stability and optic flow sensitivity following sight restoration from congenital bilateral cataracts

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Vision is crucial for maintaining balance and facilitating locomotion and navigation. Optic flow, for example, provides key self-motion cues that aid in navigation. Typically, congenital blindness results in increased postural sway during upright standing and impaired navigation abilities. Here we investigated postural stability and optic flow sensitivity in children and adolescents who underwent surgical treatment for congenital dense bilateral cataracts years after birth. Experiment 1 assessed whether cataract-treated participants (CT) rely on vision for stabilising their stance. Participants stood on a foam pad placed on a Nintendo Wii Balance Board and maintained their stance under two conditions: with eyes open or closed. Overall, CT swayed significantly more than age-matched typically sighted controls. Moreover, while controls exhibited markedly reduced body sway with eyes open compared to closed, CT displayed a notably reduced ability to use vision for sway reduction. Interestingly, CT showed gradual improvement in body sway over time following surgery, indicating partial learning in utilizing visual input to enhance stability. Experiment 2 assessed whether different radial and translational optic flow patterns elicit distinct effects on CT's body sway, thereby exploring their potential to induce illusory sensorimotor perceptions. We included two age-matched control groups: typically sighted controls and a group with experimentally reduced visual acuity to match that of CT. While CT exhibited greater sway compared to sighted controls, consistent with Experiment 1, their sway was less influenced by specific optic flow patterns. Indeed, when normalized to the individual baseline (sway while observing static dots), CT showed less affected body sway by optic flow than controls. Visual acuity influenced the sway, with blurred controls showing sway levels between CT and sighted participants. Overall, the study showed that cataract-treated exhibit only partial learning in utilizing vision for stabilization. Moreover, optic flow patterns evoke less pronounced illusory self-motion perception compared to typically-sighted individuals.
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Modality switching (and the absence thereof) modulates the redundant signal effect

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Responses to bimodal signals are faster than those to their unimodal constituents. This so-called redundant signal effect is affected by sequential effects such as modality switching, where changing modality in a random trial sequence causes a slowing of responses. Critically, while unimodal trials can follow full modality switches (e.g., an auditory following a visual signal), bimodal trials can follow only partial switches (e.g., an audiovisual following a visual signal). Thus, the effect of full modality switches on bimodal responses is unknown. Here, in addition to the standard instruction to detect auditory or visual signals, we presented tactile target signals in the random trial

sequence. Consequently, bi- and unimodal trials can follow full modality switches (e.g., an audiovisual following tactile signal). Our data show that modality switching modulates the redundant signal effect, including violations of Miller's bound, which is often interpreted as a benchmark result indicating multimodal processing interactions. We find larger violations occurring in full modality switch trials and smaller (but still present) ones in modality repetition trials. Interestingly, unlike their unimodal counterparts, bimodal responses are not (or only marginally) affected by full modality switches. Thus, the observed modulation of the redundant signal effect is largely driven by unimodal responses that are slowed due to modality switching. Therefore, understanding modality switching and its differential effect on uni- and bimodal responses will be key to fully understanding the processes underlying the redundant signal effect.
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Retinocortical function in CRB1-Associated Inherited Retinal Dystrophies

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Inherited retinal dystrophies (IRDs) are a leading cause of blindness worldwide. In CRB1-associated IRDs, mutations to a single gene cause a wide variety of sight loss profiles, ranging from early onset severe vision loss to later-onset, milder phenotypes, for reasons not well understood. With new gene therapies on the horizon aiming to restore retinal gene function, we need to characterise the impacts of the disease on retinocortical development and function and establish objective clinical trial endpoints that are applicable across a wide spectrum of phenotypes. Achieving this has been challenging due to patients' widely varying abilities and the associated variability in test feasibility and sensitivity. We used a child-friendly electroencephalography (EEG) paradigm to quantify retinocortical visual system function in a cohort of patient with CRB1-IRD. This involved recording steady-state visual evoked potentials (ssVEP) elicited by flickering sinusoidal gratings across a range of spatial frequencies embedded into age-appropriate movies. Our findings reveal significant attenuation of ssVEPs in patients with CRB1-IRDs compared to healthy controls, particularly pronounced for stimuli in the mid-to-high spatial frequency range. This attenuation was most notable in patients with moderate to severe visual impairment. Interestingly, even patients with relatively preserved visual acuity (WHO "no or mild" visual impairment), displayed markedly reduced ssVEPs, particularly in response to mid-range spatial frequencies. This highlights the ability of ssVEP measures to capture unique aspects of pathology beyond visual acuity alone. Nevertheless, ssVEP responses strongly correlated with measures of visual acuity, indicating their utility as a proxy for visual acuity in individuals with communication difficulties and for clinical trials requiring objective measures of visual function. Together, these findings underscore the value of ssVEP measures as a complement to traditional measures of visual function for characterising widely ranging disease characteristics and assessing treatment efficacy in IRDs.

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Manipulating the statistics of sensory information in multisensory category learning

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Our environment exposes us to natural correlations between multisensory dimensions of the stimuli we encounter. For example, imagine drinking your morning coffee, the darker the colour of the drink the stronger the corresponding taste. These correlations can be helpful when making categorical decisions about stimuli (e.g. is this an americano or a latte). However, the statistics of the sensory information we are exposed to naturally varies day-to-day and across the lifespan, and these variations can differ between sensory modalities, which may consequently impact our ability to combine sensory modalities to make optimal category decisions. In the current study, participants categorised novel stimuli defined by a combination of auditory (pitch) and visual (spatial frequency) dimensions. One category followed a positive correlation (high pitch + high spatial frequency OR low pitch + low spatial frequency) whilst another followed a negative (low pitch + high spatial frequency OR high pitch + low spatial frequency). Following an initial learning phase, the statistics of sensory dimensions were altered, such that the range of sampled stimuli was narrowed either on both or one sensory dimension and such that the manipulated dimension(s) fell closer to the category intersect. Following learning, rapid adaptation was observed to new category statistics and this occurred if one or both modalities were manipulated. We discuss these findings in the context of real-world scenarios, wherein we must adapt to alterations in the statistics of the sensory input received.
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Parietal tACS coupled with a visual-attentional training improves lexical access and working memory in dyslexia

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Developmental Dyslexia (DD) is a multifactorial disorder, which includes deficits in auditory-phonological processing as well as deficiencies in the magnocellular-dorsal (M-D) visual stream, responsible for the identification of graphemes and lexical units during reading. The M-D stream is associated with neural oscillations in beta frequencies (15-25 Hz). The present study aimed at investigating the possible cumulative impact of transcranial alternating current stimulation (tACS) and a visual-attentional reading training. tACS was applied to parietal sites, the main projection of M-D pathway, bilaterally at beta frequency (18 Hz), to improve the M-D functionality while also improving the capability of ventral stream areas in identifying visual word structures. Three groups of young adults (N = 37) with DD participated in the project. The first group completed 12 sessions of an adapted version of a reading acceleration training while receiving tACS stimulation; the second and third groups underwent a sham stimulation in combination with reading acceleration training and phonological training, respectively. Before and after the training sessions, participants were asked to judge the lexicality of written

words and pseudo-words while EEG was recorded. When comparing the same training paired either with tACS or sham stimulation, the N400 and P600 event-related potentials (ERPs) where differentially modulated in the tACS group suggesting a less effortful lexical and semantic categorization in the post-training session. As for time-frequency data, we expect a decrease in frontal theta band, reflecting working memory load. Moreover, we expect a decrease in alpha power in temporo-parietal regions, reflecting encoding of semantic information. Lastly, in line with this interpretation, we observed an improvement in working memory capacity, as assessed by the digit span test. Taken together, our results suggest that a combination of tACS and visual-attentional reading training lead toward a more efficient lexical/semantic categorization, possibly supported by a general improvement in working memory.
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Gaze when avoiding obstacles

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People generally look at positions that are important for their current actions, such as objects they intend to grasp or suitable spots to place their feet when walking in challenging terrain. So where do people look when walking into a room to grasp an object? Do they look where they intend to place their feet? Or do they look ahead to determine where they need to be and prepare for their upcoming grasping action? In particular, do they look at potential obstacles along their path or only at items related to the object they intend to grasp? We asked participants to walk into a room and pour the contents of a target cup placed on a table in front of them into another cup elsewhere on the table. The three meters between the door and the table was empty except for two obstacles on the floor. There was an additional obstacle on the table near the target cup. As participants approached the door, they initially mostly looked at the objects on the table, presumably to select a good position from which to pick up the target cup, considering the positions of the additional obstacle and the cup into which they were to pour its contents. As they entered the room, they occasionally looked at the obstacles on the floor, but mainly at the floor along their path. From when they crossed the first obstacle, they looked at objects on the table. They looked at the target cup while reaching for it and picking it up, and then at the cup they were pouring into. Thus, although the obstacles were important for the action, people mostly relied on peripheral vision to avoid them, directing their gaze where they would place their feet although there was nothing particularly informative to see there.
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The influence of exocentric information on egocentric distance estimates for perception and action.

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Previous research suggested distinct roles for egocentric and exocentric distance information in guiding actions like reaching and grasping. For example, 'reaching' for an apple requires estimating absolute distance from the observer (egocentric), while 'grasping' it relies on depth information (exocentric) to plan for appropriate grip size. However, our study challenges this idea by demonstrating that exocentric information also influences reaching distance. Participants interacted with a virtual 3D paraboloid protruding towards them. They were asked to either reach for its peak or base, or grasp it at these two points with their thumb and index finger. First, to independently manipulate the exocentric information, we manipulated the number of depth cues, as it has been found that an object depth appears greater when specified by more depth cues. Secondly, we varied viewing distance (near vs. far) in a way that the base of the near object aligned with the peak of the far object, making those two positions at equal egocentric distance. If reaching distance is solely determined by egocentric distance estimates, the depth interval between reaches performed at the peak and the base of an object should remain unaffected by the number of depth cues. However, both reaching and grasping tasks showed an overestimation of this depth interval with more depth cues. Furthermore, participants consistently reached for the base of a near object at a farther point than the peak of a far object, although both were physically equidistant from the observer. Perceptual judgments yielded a similar pattern of results, consistent with the reaching and grasping tasks. These results suggest that the visual system integrates exocentric and egocentric information even when egocentric information alone is sufficient to perform an action. This raises intriguing questions concerning how the human visual system selects and incorporates relevant spatial properties to represent distance.
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Temporal sensitivity in visual cortex under scotopic conditions

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Prior work has found that visual behavior is slower and involves integration over longer timescales under scotopic (rod-only) relative to photopic conditions. This difference is believed to stem partly from differences in photoreceptor properties, and it is unknown whether it persists in visual cortex. While temporal frequency-dependent neuronal activity has been thoroughly researched using functional MRI techniques under photopic conditions, this has not been studied under scotopic conditions. Ten normally sighted subjects viewed a full-screen, high-contrast stimulus flickering at rates ranging from 2-10 Hz during functional MRI scanning (3T Skyra). Each subject completed the experiment both under photopic and under scotopic conditions. Additionally, under photopic conditions, subjects viewed a drifting bar which was used to delineate their retinotopic maps with a population receptive field model. The flickering stimulus led to widespread activation along the visual cortex under both lighting conditions. Generally, the BOLD response in V1 was higher under photopic than under scotopic conditions. Most importantly, we observed an interaction between the effects of lighting condition and frequency on V1

BOLD response magnitude. Under photopic conditions, subjects exhibited the largest BOLD response for the 7.5 Hz flicker, similar to prior results. Under scotopic conditions, the largest BOLD response was observed for 2 Hz flicker, while the response to 7.5 Hz flicker was smaller. Our results suggest that under scotopic conditions, the preferred stimulus in V1 has lower temporal frequency than under photopic conditions. This is the first time that functional MRI techniques have been used to analyze frequency preferences under scotopic conditions, building on prior results found using behavioral and electrophysiological methods. Further research is needed to determine whether differences in stimulus frequency preferences are due to slower processing by rods or to additional factors along the visual pathway and cortex.
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From mice to humans: A cross-species comparison of engagement fluctuations during visual decision-making

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Over prolonged periods of time, the ability to sustain engagement tends to fluctuate. In mice, these fluctuations have been described as states of a hidden Markov model: during visual decision-making sessions, clusters of errors and biased responses indicate that mice alternate between multiple states or strategies over time. However, it remains unclear whether humans exhibit similar discrete decision strategies, especially since human experiments often provide experimenter-timed breaks. Here, we investigate the extent to which humans switch between engaged and disengaged strategies as a function of time-on-task (breaks versus no breaks), and whether the identified states and frequency of state transitions are comparable to those observed in mice. To enable cross-species comparison, we created a visual task that closely mimics a standardised procedure used in mice, developed by the International Brain Laboratory. Participants view two Gabor patches and indicate which patch has the higher contrast. To investigate the effects of time-on-task, participants complete 600 trials either without breaks, or with a break every 100 trials. We will fit a hidden Markov model to participants' reaction time data to obtain trial-by-trial assignments to engaged and disengaged states. We expect to find that participants alternate between multiple decision-making strategies, with disengaged states occurring more often when there are no breaks in the experiment. Our findings will offer insights into the dynamics of perceptual decision-making in humans, and may have implications for experimental design. This study will also provide a starting point for linking the cognitive and neural basis of decision strategies across species.

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Creating something from nothing: Symbolic and non-symbolic representations of numerical zero in the human brain

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Representing the quantity zero is considered a unique achievement of abstract human thought. Despite considerable progress in understanding the neural code supporting natural numbers, how numerical zero is encoded in the human brain remains unknown. We find that both non-symbolic empty sets (the absence of dots on a screen) and symbolic zero ("0") occupy ordinal positions along graded neural number lines within posterior association cortex. Neural representations of zero are partly independent of numerical format, exhibiting distance effects with countable numerosities in the opposing (symbolic or non-symbolic) notation. Our results show that format-invariant neural magnitude codes extend to judgements of numerical zero, and offer support to theoretical accounts in which representations of symbolic zero are grounded in more basic representations of sensory absences.

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Measuring the typicality of visual images

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How do we determine what is typical or atypical when given an example of a particular scene category? Previous studies suggest that typicality consists of a weighted average of simple features. While defining these features for simple stimuli is easy, how do we identify the specific attributes in complex stimuli like photographs? In our study, we differentiate between two concepts of typicality - conceptual (e.g., a personal car is conceptually typical, while a tractor is less) and perceptual (e.g., a rainbow-colored car is less perceptually typical than a black car) and collected both ratings for three semantic categories of standard rooms - kitchens, bedrooms, and living rooms (140 images per category, 25-50 ratings per image). We defined two sets of features - deep features and human-crafted features. For the computation of deep features, we evaluated each image by pre-trained AlexNet and used fc7 vectors. For human-crafted features, we let people define attributes in a qualitative study (N=48) to differentiate between individual exemplars, and we grouped similar characteristics into nine commonly mentioned features (e.g., number of windows, the colorfulness of the room). In a subsequent study (N=268, 23-41 ratings per image), we asked participants to rate the intensity of given attributes. Results show that both typicality measures correlate highly (Spearman's $\rho = 0.93$). Typicality measures could be better estimated from human-crafted features (adj. $R^2 = 0.59\text{-}0.81$) than from deep features (first 10 PCA components; adj. $R^2 = 0.36\text{-}0.59$). This suggests that human typicality estimates can be decomposed into simple semantic attributes such as the room size or number of chairs in standard rooms.
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People are sensitive to their uniquely patterned retinal input

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Visual exploration through eye movements involves frequent changes to the visual input on our retinae. This visual input is patterned by factors such as where we look, how often we move our eyes, and our behavioural goals. Previous research has shown consistencies in saccade behaviour within individuals over a variety of images and tasks, resulting in uniquely patterned visual input for different people. Are people sensitive to their own pattern of visual input, and can they distinguish it from the input of others? To test this, we recorded subjects' eye position while they were free-viewing pictures of natural scenes. From these gaze trajectories, we circularly cropped (7º radius) images around individuals' eye positions, to create a sequence of images for later replay at fixation. We presented these gaze replays (5s each) to subjects, with 100 replays created from a subject's own eye data, and 100 replays from other subjects' eye data. Nearly all subjects performed above chance at choosing whether a replay was theirs or not, and demonstrated higher confidence on correct than incorrect trials. Subjects responded fastest when reporting a replay was theirs (even if it wasn't), and were relatively quicker when they were correct. Interestingly, pupil size reflected ground truth, with larger dilations when subjects viewed replays that were not theirs, irrespective of their subsequent choice and its accuracy. We also found that when a subject mistook another subject's replay to be theirs, the scanpath constituting that replay tended to be more similar to their own scanpath when they viewed the same image during free-viewing. In summary, we find that people are sensitive to the visual input patterned by their own unique eye movements.

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Facial trustworthiness impressions are dynamically shaped by the spatio-temporal context

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Although we are told to 'never judge a book by its cover', trustworthiness impressions from faces significantly shape our daily social interactions. Previous research has mainly considered trust judgements as isolated, de-contextualised, and stable over time. However, in everyday life, faces are not perceived in isolation but are perceived in a spatio-temporal context, where we encounter a series of faces one after the other or sometimes in groups. Here, we showed that trustworthiness impressions are influenced by the spatio-temporal context in which faces are embedded. In the spatial domain, we found that the visual system can quickly extract the average trustworthiness of the group of people we are facing without analysing each single face in the scene – a phenomenon called ensemble perception. In the temporal domain, we demonstrated that faces in our visual history can strongly bias present trustworthiness judgments, across multiple experiments. We focused on the impact of two opposite visual biases traditionally studied separately: negative aftereffects (i.e., bias away from the past) and serial dependence (i.e., bias towards the past). We found robust negative aftereffects and serial dependence in trustworthiness judgements, confirming the influence of faces presented in the past on present trustworthiness evaluations. Importantly, we were able to demonstrate a dissociation of attractive and repulsive visual temporal biases. We modulated the exposure duration of previous faces and showed, for the first time within the same experimental paradigm, that brief exposure led to serial dependence, and longer exposure led to negative aftereffects. Overall, these results shed light on the dynamic nature of facial trust impressions and show that the spatio-temporal visual context plays a crucial role in shaping these impressions.

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Human balancing in VR under the influence of optical flow

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Human-made environments can be full of straight-lined, repetitive patterns that induce optical flow when moving past. Some patterns can even disturb human motor control and affect motor stability. We investigated how optical flow of a repetitive pattern influences stability in a human balancing task in virtual reality (VR) by analysing changes in kinematic aspects due to the presence of a stationary and moving pattern. In our experiment participants were placed in VR facing a wall with either a uniform grey (control) or a black and white vertically striped pattern and were tasked to keep their balance while standing on one or two legs. The wall was either static or moved in a linear (left or right) or sinusoidal (0.2Hz) manner. Each trial lasted 30s. In wall-movement conditions the movement started after 10s and lasted 10s, thus it was enclosed by two phases of no wall movement. Movement data was collected using an infrared camera-based motion-capture system (Qualisys Oqus) and a reduced full-body marker set consisting of 26 passive reflective markers. A static stripy pattern led to less movement of ankles, wrists and head when balancing on one leg compared to a grey background. During movement phases participants showed less stability as observed in an increased movement of their head and limbs. We also found after-effects in the second static phase in the form of continued reduced stability after the movement phase. For sinusoidal movements, the frequency of the optical flow seemed to be represented in the head and limb velocity frequency spectra which carried over into the second static phase of a trial. These results underline the effect of optical flow on human balancing. They indicate stabilising effects of static but destabilising effects of moving patterns and suggest that especially a change in optical flow negatively influences human balancing.
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Semantic consistency in identifying human actions

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People quickly recognise human actions carried out in everyday activities. There is evidence that Minimal Recognisable Configurations (MIRCs) contain a combination of spatial and temporal visual features critical for reliable recognition. For complex activities, observers

may have different descriptions varied in their semantic similarity (e.g., washing dishes vs cleaning dishes), potentially complicating the investigation of MIRCs in action recognition. Therefore, we measured the semantic consistency for 128 short videos of complex actions from the Epic-Kitchens-100 dataset (Damen et al., 2022), selected based on poor classification performance by our state-of-the-art computer vision network MOFO (Ahmadian et al., 2023). In an online experiment, participants viewed each video and identified the performed action by typing a description using 2-3 words (capturing action and object). Each video was classified by at least 30 participants (N=76 total). Semantic consistency of the responses was determined using a custom pipeline involving the sentence-BERT language model, which generated embedding vectors representing semantic properties of the responses. We then used adjusted pair-wise cosine similarities between response vectors to compute a ground truth description for each video, a response with the greatest semantic neighbourhood density (e.g., pouring oil, closing shelf). The greater the semantic neighbourhood density was for a ground truth candidate, the more semantically consistent were responses for the associated video. We uncovered 87 videos where semantic consistency confirmed their reliable recognisability, i.e. where cosine-similarity between the ground truth candidate and at least 70% of responses was above a similarity threshold of 0.65. We will use a subsample of these videos to investigate the role of MIRCs in human action recognition, e.g., gradually degrading the spatial and temporal information in videos and measuring the impact on action recognition. The derived semantic space and MIRCs will be used to revise MOFO into a more biologically consistent and better performing model.
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Expanding visual search models: New insights from confidence reports and hybrid search

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Visual search integrates bottom-up and top-down information to make goal-driven decisions, engaging processes such as attention, memory, and decision-making. Recently, we presented a model that combines an Ideal Bayesian Searcher core to incorporate top-down processing, with neural networks mainly to model bottom-up information processing. It was evaluated in four datasets and compared with other state-of-the-art models in a benchmark in different metrics (https://github.com/NeuroLIAA/visions). The present study conveys several improvements. First, we moved to an Entropy-Limit Maximization framework, which not only resulted in better performance on the benchmark but also it runs +100x faster. Second, we explored other neural networks to estimate the prior and assess target detectability. Third, we introduced a limit in the model's memory capacity. Fourth, we parameterized the visibility map to better fit the saccades' length. We evaluated the model in two new tasks: First, a Hybrid Search task, where there are more than one potential target (memory set size, MSS) and the model needs to decide how to combine those in one search. The model achieved a good performance although we did not find a clear criteria up to MSS=4. Second, we proposed a task where the search is interrupted after N fixations and participants are asked to report target location and their confidence. The model was able to accurately predict the participant's response, even if the target was not found, suggesting that it can mimic the participants' introspective processing. Moreover, the entropy of the probability map after the last fixation showed to be a good confidence predictor. Summarising, although visual search behaviour is usually modelled on the algorithmic level, our approach proves successful in modelling both details of the eye movements, as the saccade length distribution and the scanpath, as well as higher cognitive processes, as the conscious evaluation of the information available.
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Testing Stimulus Generalisation Theory of Impression Formation Within and Across Culture

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People readily judge trustworthiness based on others' facial appearance. Stimulus Generalisation Theory (FeldmanHall et al., PNAS, 2018) suggests that trustworthiness impressions of strangers can be based on visual similarity with previously encountered individuals. For example, if a stranger's face visually resembles someone who had previously been helpful (or not), the stranger is judged to look more trustworthy (or untrustworthy). Prior work on this theory has relied on inducing this social learning in a lab-based paradigm, lacking generalisability to real-world learning over time with natural exposure to real individuals. Here we validated this key theory in a more naturalistic context using facial morphing: we tested whether existing attitudes towards prior known individuals (celebrities) predicted trustworthiness impressions of strangers' faces which were visually morphed to resemble these identities. Across three studies (Total N = 291) and two world regions (UK, Australia), as predicted, we found a significant relationship between prior attitudes towards these individuals and trustworthiness impressions of strangers' faces with implicit resemblance to these individuals. A multi-level model further indicated that our results cannot be fully explained by variations in the facial appearance of the different face identities or participants' individual differences. Taken together, our results support Stimulus Generalisation Theory, suggesting that natural longer-term attitudes can influence visual trustworthiness judgements. Our findings demonstrate the importance of our social environment in forming perceptual judgments of strangers.
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Contributions of additive and multiplicative noise to lateral and in-depth speed uncertainty

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The traditional approach to measure precision of visual speed (i.e. discrimination thresholds) has relied on psychophysical discrimination tasks, which can be cumbersome and prone to bias, especially without expert participants. Moreover, motion-in-depth thresholds are often found to be higher than those for lateral motion, a finding at odds with everyday visuomotor performance. In this study, we use a pursuit model to assess speed observation uncertainties under three different motion conditions: random walk, linear, and non-linear, incorporating both lateral and depth movements. Participants (N=9) tracked a moving target within a virtual environment. The target, white against a dark background, moved on a sagittal plane 0.5m below eye level. For each trial, we calculated target and gaze speed, and determined tracking accuracy and delay by analyzing cross-correlograms between boths speeds. Additionally, we used the sensory phase of a pursuit model (Orban de Xivry et al., 2013), consisting in a Kalman filter, to estimate additive and multiplicative observational noise by modeling the retinal slip (the speed differential between target and gaze). Our results indicate that perception of depth motion is less accurate in the random walk condition. Nevertheless, in scenarios characterized by increased motion predictability, the perceptual uncertainties for lateral and depth movements are comparable, especially when retinal speeds across dimensions align. Moreover, the uncertainties estimated were not larger than those derived from classical psychophysical methods, suggesting that motor noise did not markedly influence the estimates. Predominantly, additive noise-rather than multiplicative noise-accounts for these uncertainties, in line with computational models of visual motion. By adopting action-based methods over traditional psychophysical judgments, this study challenges the long-held view that lateral and in-depth motion significantly differ in perceptual uncertainty levels.
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Does object movement or sound affect inter-item perceptual similarity for object categorisation?

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Previous studies of object categorisation have highlighted the role of inter-object similarity but have typically focussed on static object shapes. However, object perception benefits from the integration of multiple inputs, yet how these processes underpin object category formation is still unclear. In particular, object categories may be defined by similarities in shape, movement and sounds. We conducted two experiments to explore the influence of both motion and sound on shape space. We adapted a previous circular shape space to create 36 novel 3D objects and applied five different motion patterns to these shapes. In Experiment 1, using a within-subjects design, participants rated the similarity pairs of object shapes which varied in their distance on the shape space. Furthermore, the object pair was presented across three motion conditions: static-only, same, or different motion. Perceived shape similarity of moving objects differed relative to static counterparts: ratings to object pairs presented with the same motion received higher inter-shape similarity ratings than object pairs shown with different motions. To investigate whether both motion and sound would jointly affect the object shapes perceived similarity, in Experiment 2 we adopted the same paradigm but added five correlated movement-sounds to all the object shapes. All object pairs were presented across three motion conditions (static-only; same; different) and two sound conditions (sound; silence) in a fully factorial design. Our results suggested a weaker effect of sound than of motion on perceived shape similarity. Object motion might directly affect perceived inter-object similarity by revealing shape features from novel viewpoints, whereas the role of sound in categorisation may be indirect and based on learned associations. Moreover, each of these cues may affect the categorisation of objects independently. This research offers insights into the role of object audiovisual motion on the categorisation of novel objects.

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Understanding preferred distance in human-drone interaction

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In two experiments, we transferred the paradigm of interpersonal distance regulation to the interaction with drones. In the first experiment, conducted in augmented reality using a simple spherical drone model, we explored how both hovering height and approach angle affect the preferred distance. Drone height above the ground had a strong effect. We conducted a second experiment, also in augmented reality, to gain a deeper understanding of the factors that may influence this effect. In addition to the simple spherical drone model used in the first experiment, we also varied its appearance and attachment to the ground. We discuss to what extent social aspects and subjectively perceived danger influence the preferred distance for interaction with drones.

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Influence of manipulability of objects by hand on evaluation of aesthetic arrangement

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In our previous studies, we have found that right-handed observers prefer a rightward arrangement of objects on concrete natural backgrounds although they prefer the central arrangement of objects on abstract backgrounds (Nakajima & Ichikawa, 2008, Transaction of Japan Society of Kansei Engineering [TJSKE]). For objects that are difficult to grasp by hand (e.g., sea urchins, chestnuts in bur) and for left-handed observers, there was no such a right-side preference, but a preference for a centered arrangement (Matsuda, Ichikawa, Nakajima & Kouroki, 2014, TJSKE). In this study, we examined the effects of left and right-handed manipulability on object arrangement preferences for right-handed observers. In Experiment 1, the object was a left and right glove, which was placed in five different horizontal positions (±10.8, 5.4, 0deg from the center of the frame) on a naturalistic background (snow field, or wooden floor) in a frame (30.8deg x 10.8deg). Three different glove images were prepared, each showing the back and palm of the hand. Participants rated their impressions for each of pictures. We found that the right-hand glove was preferred in the rightward position and the left-hand one in the leftward position. The back of the hand was rated higher than the palm. In Experiment 2, participants were asked to touch the outer frame of the display with their right or left hand. Ten natural objects were placed in three different positions (±5.4, 0deg from the center

of the frame) on a uniform natural background (e.g., a fire balloon in the air, a flower in the meadow). Participants rated their impressions. We found that the opposite hand position resulted in lower ratings. These results suggest that the manipulability of the object in each hand affects the evaluation of the aesthetic arrangement for objects in the picture frame.
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Asymmetries in facilitation and interference in holistic face processing

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A hallmark of face specificity is holistic processing. It is typically measured by paradigms such as the part–whole and composite tasks. However, these tasks show little evidence for common variance, so a comprehensive account of holistic processing remains elusive. One aspect that varies between tasks is whether they measure facilitation or interference from holistic processing. In this study, we examined facilitation and interference in a single paradigm to determine the way in which they manifest during a face perception task. Using congruent and incongruent trials in the complete composite face task, we found that these two aspects are asymmetrically influenced by the location and cueing probabilities of the target facial half, suggesting that they may operate somewhat independently. We argue that distinguishing facilitation and interference has the potential to disentangle mixed findings from different popular paradigms measuring holistic processing in one unified framework.
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Contextual cueing relies on attentional guidance: Evidence from searching and responding fixations in natural scenes

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In visual search, humans find targets faster when they appear in a repeated visual context (contextual cueing effect). It is still unclear whether this effect is due to a context-enhanced guidance of attention or due to response-related processing. Here, we aimed to distinguish between these two candidate underlying mechanisms. To this end, we investigated searching and responding eye fixations to dissect the visual search process in an attention and a response phase. In two experiments, participants searched for a letter superimposed on natural scenes and identified the letter as fast as possible. One half of trials showed repeated scenes, the other half showed novel scenes. In Experiment 1, repeated scenes were always shown with the target at one location. In Experiment 2, repeated scenes could be associated with one target location, two alternating target locations, or with one screen side. We found that the number of searching but not responding fixations was reduced by context repetition. Further, the duration of neither searching nor responding fixations was affected by context repetition. The contextual cueing effect for manual response times developed in parallel with the effect on cumulative durations of searching fixations. However, this development was strikingly different from effects on cumulative duration of responding fixations. Thus, this makes the case for attentional guidance as underlying mechanism of contextual cueing.

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Does the feed-forward sweep influence the generation of top-down predictions?

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Low-spatial frequency information and statistical regularities within our environment are thought to aid visual processing through top-down influences on bottom-up processing. For example, the feed-forward sweep involves low-spatial frequency components of visual inputs rapidly propagating up the visual processing hierarchy and providing coarse estimates of sensory scenes. These estimates then feedback to lower visual areas to constrain possible perceptual interpretations. Top-down influences on visual processing also arise by exploiting environmental statistical regularities to generate predictions about expected inputs. Despite both mechanisms involving feedback to lower visual areas, it remains unknown if the visual system uses concurrently presented low-spatial frequency information to predict co-occurring stimuli. To assess this, we collected electroencephalographic data from 20 participants (intended final sample of 40) while presenting them with objects embedded in visual scenes. Each of the two objects could be displayed in one of two scenes, with each scene having a more frequent object pairing. This produced expected and unexpected conditions. Visual scenes contained exclusively low- or high-spatial frequency information and the embedded image contained only high-spatial frequency information. Participants were also presented with blocks of object only trials. Support Vector Machines were trained to classify object identity in object plus scene trials by being trained on object only trials. We assessed differences in classification accuracy for expected and unexpected images within each scene spatial frequency condition. We hypothesised that significant decoding differences between expected and unexpected pairings would occur earlier for low- compared with high-spatial frequency scenes. Our preliminary results show significant above-chance decoding across all four conditions, ranging from 74-484 milliseconds. However, no significant decoding differences were found between expected and unexpected objects in either the low- or high-spatial frequency conditions. Based on the data collected so far, we did not observe evidence that low-spatial frequency information influences the generation of top-down predictions.

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Spatial frequency information processing on the synchrony perception for audiovisual stimuli

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Perception of synchrony for audiovisual stimuli is crucial for audiovisual integration processing. Many perceptual phenomena induced by audiovisual integration occur within a temporal binding window (i.e., tolerance range of synchrony perception) of audiovisual stimuli. Various factors modulate the synchrony perception processing for audiovisual stimuli. Previous studies have found that the spatial frequency (SF) of visual stimuli alters the perceived timing of subjective simultaneity. In this study, I specifically examined the processing of SF information on synchrony perception for audiovisual stimuli using visual stimuli with multiple SF component. I compared the correlation coefficients of the point of subjective simultaneity (PSS) between visual stimuli with low-SF/high-SF and composited these two SF (composition-SF) components. The PSS values of audiovisual stimuli were measured by determining of the two audiovisual pairs perceived as more simultaneous (i.e., the dual-presentation timing task). In the results, the PSS value of composition-SF stimuli (M = 2.46 ms, SE = 4.75) was intermediate between low-SF (M = -8.61 ms, SE = 4.02) and high-SF (M = 4.28 ms, SE = 5.31) stimuli. The correlation coefficients of the PSS value were marginally higher between high-SF and composition-SF stimuli than between low-SF and composition-SF stimuli. These results suggest that the higher SF component more strongly contributed to the synchrony perception of visual stimuli with multiple SF components. This finding helps elucidate how visual information, which is related to processing speed of visual stimuli, is processed in the synchrony perception for audiovisual stimuli.
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The role of stereopsis in face processing

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Most of the extensive literature on face perception is based on stimuli presented in 2D. However, under typical real-world conditions, faces are volumetric and have 3D structure. To evaluate the influence of stereoscopic depth information we used a novel visual search paradigm with stereoscopically rendered images of faces to assess low and high -level visual processing. We hypothesized that stereoscopic viewing would make faces more salient and improve performance relative to 2D. Stimuli were presented using a mirror stereoscope, either with or without binocular disparity. In both experiments, the stimuli were presented in a semi-circular array; all faces were equidistant from the fixation point. In Experiment 1 (orientation task), an array of the same faces was presented, and the target face was tilted 15 deg to the left or right. The distractor faces were rotated in the opposite direction. In Experiment 2 (recognition task), the target face was shown, followed by an array of different faces. In both experiments, observers indicated if the target face was present, the likelihood was 50%.
Proportion correct was recorded and used to compute d' (sensitivity). In both experiments, we found no significant differences between the 2D and 3D conditions (Experiment 1: $F(1,11) = 0.00$, $p = 0.97$; Experiment 2 $F(1,14) = 0.16$, $p = 0.70$). Bayes factors of (0.52 and 0.31) for Experiments 1 and 2 provided moderate to strong evidence for the null hypothesis. Our data provide no support for an advantage of 3D stereoscopic viewing of faces for either low or high -level tasks. In ongoing studies, we are evaluating performance on similar tasks using 2D and 3D objects to determine if the lack of 3D advantage is due to the privileged nature of face processing or to the structural similarity of human faces.
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Do children benefit from multisensory over intrasensory information in their categorisation of familiar objects?

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The emergence of semantic animate categories, such as 'cow' versus 'horse', occurs early in development. However, the optimal integration of multiple sensory cues arises in later childhood. Categories of objects in the real world are mainly based on multisensory features but it is unclear whether children can benefit from multiple object cues and, moreover, whether their categorisation benefits more from multisensory over intrasensory cues. In this study, we compared children's categorisation performance to familiar objects (images of animals) across combinations of two crossmodal (e.g., a 'mooing' image of a cow) or within modal (e.g., an image of a cow in a barn) cues. To test for a benefit of multiple cues, we compared performance on both conditions to the presentation of a unisensory cue alone (e.g., an image or sound of a cow). We measured semantic category accuracy and response times across different ages of children to investigate the role of development. Using a mixed design, a sample of 126 children aged 6-12 years partook in a computerised task in which they categorised images of animals as belonging to a 'farm' or 'zoo'. There were three main conditions; unimodal (V-only or A-only), audiovisual (AV), or visual-visual (VV) informative cues. Children were grouped into three developmental groups, defined by both their ages and school-grade level, to control for working memory constraints. Results indicated a progressive improvement in categorisation performance across the developmental groups with older children being more accurate and faster at categorising stimuli in the audiovisual condition as compared to the youngest developmental group. Differences across cue conditions were also evident. Our findings provide insight into the type of sensory information that children can incorporate when making semantic category judgements and how the ability to use multisensory cues, as opposed to unisensory cues alone, changes across development.
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Source estimation of visual spatial attention: a multifocal MEG study

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Visual spatial attention aids the selection of relevant information from a visual scene. The cortical origin of visual spatial attention remains incompletely understood. Functional magnetic resonance imaging (fMRI) studies have shown that focusing attention on a certain location in the visual field has retinotopically specific effects in multiple visual areas. FMRI studies are, however, limited by poor temporal resolution. Here, we employed multifocal magnetoencephalography (MEG) to map the dynamics of spatial attention. Multifocal stimulation refers to the simultaneous stimulation of multiple visual field regions using orthogonal stimulation sequences. Here, the visual field was divided into 24 regions. MEG data (N = 20) were collected during three different task conditions: task at the fixation point, task at a target region in the right visual field, and task at a target region in the left visual field. In addition, MR images were collected for cortical source and head geometry models, and multifocal fMRI data for localization of cortical visual areas. Spatial attention modulated the visually evoked responses. Here, we compare different source estimation techniques in locating the retinotopic MEG responses and the spatial attention effect on the cortex.

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Motion compression by surround motion

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It has been suggested that the visual system extrapolates the perceived position of moving objects to compensate inevitable neural delay of retinal inputs (Nijhawan, 1994). This extrapolation hypothesis accounts for visual illusions such as the flash-drag effect, where a flashed target nearby a moving stimulus appears to be shifted in the motion direction (Whitney & Cavanagh, 2000). What would happen if the target was moving in the same direction? The extrapolation hypothesis predicts that the target would appear to move faster and to be more shifted in the motion direction. Contrary to the prediction, however, we here show that the moving object is perceived to stand still at the shifted position. In our psychophysical experiment, a wide grating pattern suddenly began to drift at 11 deg/s for 1.2 s. Nearby the grating, a small target bar appeared and moved in the same or opposite direction of the grating for a variable period, then disappeared. The perceived onset and offset positions of the target (and therefore the travel distance) were measured using an adjustment method. Parametric investigations showed that motion compression (i.e., the perceived travel distance of the target was near zero) profoundly occurred when the target moving in the same direction as the target was onset at the same timing as the onset of the grating motion, and it persists for ~150 ms (similar to the temporal freezing illusion; Motoyoshi, 2007). We interpret this motion compression as a consequence of spatial suppression of local motion signals and a shift in the position coordinate by a large-field motion, partially consistent with the explanation for perisaccadic spatial compression (Ross et al., 1997).
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Characterizing individual differences in selection history bias manifested in goal-directed reaching movements

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Everyday interactions often require the selection of a single target object from multiple possibilities (distractors). A recent framework of attentional control suggests that, in addition to perceptual salience and current goals, object selection is guided by selection history. Here, we examined how this interplay between target and distractor history manifests in individual differences in target selection for goal-directed reach. We used a priming-of-popout (PoP) paradigm combined with continuous tracking of reaching movements. Participants reached for an odd-colored target among homogeneous distractors while we systematically manipulated the trial sequence of target and distractor colors in six conditions: both target and distractor colors were repeated and full swap condition, where target and distractor colors were swapped. In partial repetition conditions, either target or only the distractor color was repeated from a previous trial while the counterpart was in a new color. In partial swap conditions, either the target was swapped with a previous distractor or only distractors were swapped with a previous target color. Reach trajectories were recorded and attraction scores taking single target reach trajectory as baseline were calculated to evaluate the performances in the six conditions. For each participant, we took their maximum attraction score and the timing of it per condition, analyzed them with t-SNE analysis and k-means clustering and we found four distinct sub-groups, with four strategies in terms of attentional target selection and selection history. In Group 1 both target facilitation and distractor inhibition accounted for the PoP effect; Group 2 & 3 only showed distractor inhibition while they differed in terms of attentional weighting of target and distractors; Group 4 only utilized target facilitation. Our findings emphasize that selection history triggers a dynamic interaction between the facilitation of the target and the inhibition of distractors, which in results in individual differences in their target selection strategies.

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Is saccadic target selection driven by luminance or brightness?

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Saccadic eye movements are controlled by neuronal circuits of varying complexity. The fastest saccades may be directly driven by the superior colliculus, while slower saccades can be affected by visual cortical activity. Here, we explore whether saccades to blue and yellow chromatic targets are mainly driven by luminance or by heterochromatic brightness (Baker & Mollon, 1993). Each trial began with a central fixation point, which was followed by the presentation of two saccade targets, one yellow and one blue, at an eccentricity of 4 deg at a 30 deg angle above and below the horizontal line, either on the left or right side of the screen. Three different paradigms controlled the timing of fixation and target presentations. The target could appear right after fixation offset, there could be a 200 msec

gap between the two, or they could overlap by 200 msec. Observers were instructed to direct their gaze towards the circle that appeared more visually salient as fast as they could. Yellow and blue stimuli were set at intensities of 0.05, 0.15 and 0.485; these parameters were chosen so that the pair with yellow at 0.05 and blue at 0.485 had the same luminance (7.28 cd/m²), and the pair yellow at 0.15 and blue at 0.485 had the same perceived brightness. At equi-luminance, the blue target was selected significantly more often than chance, for both latency conditions. Choices were close to 50% for the equi-salient pairing. For both pairings, the blue choices were higher for the longer latency trials than for the shorter half of trials. Our results confirm the existence of an S-cone input to the circuits driving the very fastest saccades (Hall & Colby, 2016). They also show that at longer latencies saccades are more determined by their perceptual attributes such as brightness, rather than low-level luminance.
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A novel size illusion: The inner tube effect

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When a target object physically overlaps in some way with a narrow, extended background element – such as a thin rectangle or tube – the perceived size of the target can appear to change quite dramatically. We first noticed this effect in the context of the "rocking line" illusion (RLI; Thornton & Todorović, 2023), where we believe it serves as one mechanism responsible for generating the non-veridical impression of tilted motion. Here, we demonstrate that this size modulation effect is much more general, and can easily be seen in completely static displays. As with the RLI, the overall scale of the display seems to play an important role, as does the proximity of the target and background element borders. Interestingly, the nature of the size change – whether the target appears thinner or thicker – is a function of the luminance contrast step between the target and the background. We provide an online, interactive demo, making it possible to explore the relevant parameter space. While it seems likely that what we are calling the "inner tube" effect can be explained in terms of known properties of contrast border ownership and/or masking, we have yet to find a definitive explanation.

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Gaze-SPV: Enhancing Prosthetic Vision for Object Recognition by including Gaze

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Restoring vision to the blind or visually impaired is a highly aspiring goal. Cortical prosthesis offer a promising avenue towards this, but one of the main challenges is to provide effective stimulation to the cortex via the visual prosthesis to enable performance of various tasks. In this study, we aim to enhance the functionality and the quality of the percepts generated by simulated prosthetic vision (SPV). We propose a novel approach to SPV that emphasizes the inclusion of gaze information into the stimulation in order to optimize object recognition performance. This is because task-based representation of the information and incorporating gaze is an essential step for future real-life applications. Our proposed method, Gaze-SPV, comprises four deep learning units: an Encoder, the Simulator, the Sighted Unit, and the Blind Unit. These units collaboratively capture stimuli, simulate cortical implant stimulation, and mimic human perception. Training consists of optimizing the Encoder and Blind Unit through perceptual loss and cross-entropy functions. Our results indicate that the stimulation patterns proposed by GAZE-SPV differ importantly from those generated by a system that does not include gaze information. The method is adaptable to include peripheral vision and is more meaningful for recognition of the surrounding environment. In a pilot study we have compared the SPV in healthy observers, leveraging eye-tracking technology to incorporate real-time gaze locations. The preliminary results suggest improved recognition performance with Gaze-SPV derived stimulation patterns. We conclude that prosthetic vision focussed at object and scene recognition in real-world scenarios may be enhanced by integrating gaze information.
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Scanning in three-dimensional space by visual attention: effects of spatial composition of the background

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There is growing interest in the properties of scanning three-dimensional visual space by attention. Revealing the properties is necessary for knowing the target cognition characteristics of humans in daily life in real world, as well as for designing virtual world in which humans could more easily operate. In the present study we investigated experimentally the properties of attention shift in three-dimensional space with using shape matching tasks between two spatially separated objects. Of eight items arranged in a circle around a fixation point on a liquid crystal display, six were distractors and were small square. The other two, placed in opposite side to the centre, were targets, which were either vertical or horizontal rectangles. They oriented the same direction with a probability of 0.5. Participants viewed these images dichoptic through mirrors. Their task was to determine whether the targets were oriented the same direction or not. In some conditions the targets appeared at on the front parallel plane, in the others they were separated in depth direction. In addition, there were three background conditions; a two-dimensional background plane consisted of random dots was presented at fixation plane, in front of or behind the all items. As expected, participants responded slower when the targets were separated in depth. There observed significant anisotropy in the effect of the background, with participants' performance decreasing as the background

became more anterior to it, while the effect was negligible when the background had uncrossed disparity. This strongly suggests that the properties of attentive scanning are based on the apparent spatial separability rather than retinal separability of items. The neural basis of these findings will be discussed here.

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Spatiotemporal Models for Multisensory Integration in Mammals

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Multisensory integration is a process of redundancy exploitation, in which the brains combine information across the senses to obtain more reliable and salient perceptual responses. While the neural and behavioural correlates of multisensory processing are increasingly better understood, little is knowns as to how the dynamic patterns of sounds and light reaching our senses are processed and combined to determine the integrated percept. This study demonstrates how a biologically plausible neural architecture, performing elementary analyses of luminance and sound-level, is sufficient to jointly explain the spatiotemporal determinants of audiovisual integration and crossmodal attention. When implemented using an architecture analogous to the motion detectors found in the insect brain, such low-level analyses can broadly reproduce human's, rat's and monkey's behaviour–as tested in a large-scale simulation of sixty-nine classic psychophysical eye-tracking, and pharmacological experiments on the spatial, temporal, and attentional aspects of multisensory integration. Multisensory speech and spatial illusions, attention maps, and Bayesian Causal Inference all emerge from a population of local correlators, that operate across time, space, and the senses.

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Visual Attention in Judging TikTok Video Trustworthiness: Effects of Speaker Gender, Veracity, and Communication Modes

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How do people receive and trust information on social media? Previous studies found that video and audio enhanced trust more than text-only due to richer non-verbal information. However, the comparison between video and audio on trust remained unclear. This study examined how communication modes (audio, video, subtitles, and their combinations), speaker gender, and content veracity affect perceived trustworthiness. In a within-subject design, 31 participants watched 20 TikTok videos (5 communication modes * 2 genders * 2 veracities) and rated the trustworthiness (0-100) of the speaker and content with eye movement tracked. Interestingly, female speakers (ANOVA, $F(1, 30) = 14.65$, $p = 0.001$) and real content ($F(1, 30) = 79.08$, $p < 0.001$) were perceived as more trustworthy, but no significant effects of communication modes on trustworthiness ratings of the speaker ($F(2.80, 83.91) = 1.95$, $p = 0.133$) and content ($F(3, 90) = 1.11$, $p = 0.348$). Non-parametric tests were used to examine the non-normally distributed eye movement data. Significant effects of communication modes on saccade count (Friedman test $\chi2 = 66.45$, $p < 0.001$), saccade amplitude ($\chi2 = 95.87$, $p < 0.001$), and fixation duration ($\chi2 = 59.67$, $p < 0.001$) were observed, possibly due to subtitles caused a shift of visual attention from faces to subtitles, revealed by analysis of interest area. Wilcoxon signed-rank test showed that viewers focus less on mouths ($V = 86.00$, $p < 0.001$) and more on eyes ($V = 353.00$, $p = 0.039$) of speakers delivering fake versus real content. The findings highlight the influence of speaker characteristics and content authenticity on trust judgement. Communication modes influenced visual attention but not trust, supporting the idea that video and audio have similar effects on trust. The current study provides insights into the perceptual and cognitive processes of trust evaluation.

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Attention facilitates three-dimensional shape from shading

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The visual system utilises several monocular cues to perceive the three-dimensional environment. One critical cue is shading, whereby the three-dimensional shape of an object can be inferred by shading patterns in a process termed "shape from shading". Shape from shading has been considered an early and pre-attentive process, however recent evidence has suggested that there exists a later stage of processing for shape from shading that requires top-down attention. Here, we investigated this proposal using event-related potentials to record brain activity with great temporal resolution, whilst participants passively and actively viewed two-dimensional or three-dimensional shaded stimuli. We found an early stage of shape from shading around 150-200 milliseconds post stimulus onset that occurred during passive viewing, demonstrating processing for shape from shading without guided attention to the stimuli. Further, we found evidence for a right hemispheric lateralization of this early processing only during active viewing, suggesting that guided attention facilitated right hemispheric processing for shape from shading. Additionally, we found a later stage of processing for shape from shading around 290-350 milliseconds post stimulus onset that occurred only when attention was guided to the stimuli. Therefore, this indicates that guided attention is necessary for later-stage processing related to shape from shading. Finally, differences in processing between convex and concave three-dimensional shape were observed at both early and later stages of processing, highlighting differences in the processing of specific three-dimensional shapes. This research presents evidence for two separate processes involved in three-dimensional shape from shading. Moreover, it suggests that guided attention facilitates early processing for shape from shading but is necessary for later-stage processing related to three-dimensional perception.

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The development of visual crowding

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Crowding, the disruption to object recognition from clutter, places fundamental limits on vision. While crowding primarily affects peripheral vision in adults, children show substantial crowding in foveal/central vision, with a protracted period of development. These foveal crowding elevations would restrict key processes like reading, making it important to characterise this developmental trajectory. Current estimates vary widely however, with adult-like performance estimated to occur anywhere from 6 to 12+ years old. We aimed to resolve these ambiguities and characterise this developmental trajectory using methods optimised for the measurement of crowding in children. Participants were children aged 3-12 years (n=94) and adults (n=25) with typical vision, who viewed a foveal 'Pac-Man' target (like a Landolt-C) and judged its orientation (4 cardinal orientations). Targets were black, shown either in isolation or surrounded by 4 black 'ghost' flankers, with stimulus sizes and inter-element spacing (1.1x stimulus size) scaled using QUEST. Performance in the isolated condition measured acuity via gap-size thresholds, which were high at 3-4 years and rapidly dropped to adult-like levels at 5-6 years, consistent with prior reports. Gap-size thresholds rose when flankers were added, demonstrating foveal crowding at all ages. These elevations were highest at 3-4 years, remained elevated at 5-6, and dropped to adult-like levels from 7-8 years onward. Thresholds decreased at all ages when the contrast polarity of flankers was reversed (white), demonstrating a selectivity for target-flanker similarity that matches crowding in peripheral vision. Comparison of our thresholds against prior studies suggests that later estimates for the age of maturity are likely driven by measurement confounds and the underestimation of adult crowding. Our demonstration that foveal crowding develops around 7-8 years nonetheless suggests a prolonged maturation of spatial interactions in visual cortex, consistent with proposals that later-stage processes in the visual hierarchy (like crowding) develop more slowly than earlier processes.
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The Effectiveness of a Mailed Contrast Sensitivity Test in prioritising cataract patients for surgery

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Background and Purpose: Prioritizing the most urgent cases in cataract waiting lists requires practical and economical solutions. Here, we investigated the feasibility of mailing patients a pen-and-paper contrast sensitivity test to identify eyes that require surgery. Methods: Using a cross-sectional study design, the SpotChecksTM contrast sensitivity(a near chart with small spot targets of decreasing contrast printed on an A4 card) test was mailed to patients (n=233) waiting for a cataract assessment, along with a prepaid return envelope. Response rates were tabulated (stratified by age, sex, and socioeconomic status), and test scores were analysed to determine how well the home tests predicted which eyes were subsequently referred for surgery. A subset of these patients (n=39) also received in-person follow-up clinical testing to assess the accuracy of their home data. Results: Of the 233 patients, 108 (46%) responded. There were no significant differences between respondents and non-respondents in terms of age, sex, geographical location, or socioeconomic status (all $p > 0.05$). The home-test contrast sensitivity scores had an AUROC {± CI 95%} of 0.69 {0.61 – 0.76} for predicting which eyes were later listed for surgery. Machine learning was used to combine contrast sensitivity scores with the patient's visual acuity (extracted from the patient's medical record) to further improve the prediction (AUROC {± CI 95%} = 0.77 {0.70 – 0.83}). Follow-up testing in a subset of patients (n=39) indicated home contrast sensitivity scores correlated with other clinical measurements including biometry signal-to-noise ratio ($p=0.032$), LogMAR acuity ($p<0.001$) and Pelli-Robson contrast sensitivity ($p<0.001$). Thirty-six were asked about their preference, and 26 of them (72%) said they preferred the idea of a pen-and-paper test over a digital app (14% had no preference). Conclusions: Mailing people pen-and-paper sight tests may be a feasible, "low-tech" technique to help assign priority to patients on cataract waiting lists.
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Crossmodal art perception: A behavioral and fMRI study

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We studied behavioral and neural underpinnings of crossmodal emotional congruency on art perception. Paintings and music excerpts were first piloted and rated as 'happy' or 'sad'. In the experiment, the paintings were presented without music (unimodal condition) or with music (crossmodal condition). In the crossmodal condition, the music could be emotionally congruent (e.g. happy painting, happy music) or incongruent with the painting. We included Fourier scrambled versions of the paintings to control for the effect of semantics. We tested 20 participants with fMRI while they rated the presentations. 2x2 repeated measures ANOVA analysis revealed that liking ratings for modality (crossmodal or unimodal) × semantics (normal or Fourier-transformed paintings) were notably stronger for unimodal presentations compared to crossmodal presentations ($p<.001$). Similarly, liking ratings were higher in the emotionally congruent condition compared to the incongruent condition, with a significant interaction effect with semantics ($p<.001$). This suggests that semantic information at congruent trials enhances the beauty ratings. The fMRI results showed that the crossmodal-unimodal contrast predominantly activated auditory and emotion-processing regions, including the Heschl Gyrus, Superior Temporal Gyrus, and Insular Cortex. Further, congruent and incongruent presentations showed marked differences in related sensory areas. Congruency × Semantics revealed heightened activation in emotion-related regions, specifically the Right Putamen and Amygdala. Overall, these findings emphasize the complex connection between emotions and semantic processing in multisensory art experiences.

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Search asymmetries for dynamic faces

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Faces are important stimuli. A key feature of faces is that they are dynamic, with discriminable temporal orders: Humans can discriminate whether dynamic faces are presented in their natural (forward) or unnatural (backward) temporal order. In the current study, we investigated the saliency of temporal order in a visual search paradigm. In particular, we tested whether search times for forward and backward dynamic faces (among backward and forward face distractors, respectively) were differently affected by the face inversion effect. We conducted two experiments using muted grayscale videos of models vocalizing a well-known text. The experiments only differed in terms of the target type; the target was either forward or backward in time. Participants indicated whether the target was present or absent. Targets were presented in matrices together with 3, 8, or 15 distractors. Faces were either presented upright or inverted in separate blocks. In the upright condition, search slopes were as expected: Increased numbers of distractors increased RTs for both forward and backward targets. Interestingly, in the inverted condition, the search slope was almost flat for forward targets. This finding suggests that the targets stood out more strongly than in any other condition (also supported by the fastest RTs compared to all other conditions). By contrast, the search slope for backward targets in the Inverted condition was steep: RTs clearly increased with the number of distractors. These effects cannot be explained by sensitivity or criterion differences alone. Taken together, our results suggest a search asymmetry for forward and backward targets. While forward targets were found highly efficiently when presented inverted, backward targets were not. These results suggest that the saliency of forward and backward targets depends on the orientation of the faces. Alternatively, observers may employ different strategies or use different cues depending on the stimuli and tasks.
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Hand-dependent influence of grasp planning on visual processing

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Most hand actions are guided by visual information. It has been reported before that actions also facilitate visual information. However, the execution of action is accompanied by the movement of hands, which may interfere with the processing of visual targets. Here, we tested whether or not the planning of action would also affect the visual processing of targets before hand movements. A single target (Single) or a target surrounded by flankers (Surrounded) was presented on the screen while the EEG data were recorded. The target and the flankers flickered at different frequencies so that their response could be separated with steady-state visual evoked potentials (SSVEPs). We compared the SSVEP of the target on trials where participants planned to grasp the target (Grasp), planned to perform a target-irrelevant task (Key Release), or planned to estimate the size of the target (Estimate). All participants were right-handed. A transparent disc was placed on top of the target so that participants could grasp the object under the Grasp condition. We found that compared to Key Release, a target-irrelevant task, grasp planning does not affect the response to a single target but enhances the surround suppression of the flankers on the targets. This effect was observed only for right-hand grasping but not left-hand grasping. We also compared the results with a perception task (Estimate) to further examine whether or not the influence was specific for action. Again, grasp planning induced stronger surround suppression compared to the perception task. Overall, these results provide convincing neurophysiological evidence that even the planning of goal-directed action affects the visual processing of the target. Future studies can further examine the neural mechanisms of such influence.
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The Neural Underpinnings of Aphantasia: A case study of identical twins

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For those with aphantasia, it is difficult—or even impossible—to visualize a crisp red apple in their minds. This lack of visual imagery bleeds into visual memory, with aphantasics recalling fewer objects (and in less detail) from memory than controls, despite intact perception and semantic memory. In other words, aphantasia nearly selectively impacts memory for visual details, meaning that those with aphantasia can serve as a "knock-out" model of visual memory. What causes this lack of visual memory, and—if not visual—what is the content of their memories? Here, we leveraged the shared genetics and experiences of a unique set of identical twins—one with aphantasia (VVIQ = 24), and one without (VVIQ = 47)—to answer this question. As identical twins are as similar as possible for two individuals, this means that by running these twins through a series of mental imagery tasks during functional magnetic resonance imaging (fMRI), we can selectively isolate neural differences unique to their differing imagery experiences. We collected perceptual representations during novel image encoding, and collected mnemonic representations of those same images when the twins subsequently recalled them using mental imagery. Using a support vector machine searchlight, we found that although the imager twin had slightly more voxels capable of decoding representations between perception and memory—and with slightly higher accuracy—we found a surprising degree of decodable visual information in the aphantasic twin's mental imagery. However, we found the dissipation of this visual information when the aphantasic instead conjured images of familiar items from longer-term memory stores. Interestingly, functional connectivity patterns may underlie this lack of visual information, with the aphantasic having weaker functional connections between occipitotemporal and frontal/parietal regions. Overall, this unique case of identical twins provides a nuanced insight into the neural underpinnings of aphantasia and visual memory.
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Natural scene processing based on texture information: psychophysics and EEG

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Human visual system can effortlessly recognize the category of natural scene images (beach, mountain, etc.). Traditionally, such visual perception is based on the spatial layout of natural scenes. However, recent studies in psychophysics and computer vision suggest that global information is important for the early phase of visual scene perception. To investigate whether the natural scene perception is supported by the global information and how much it would be, we measured the classification accuracy for 250 natural scene images and their two types of spatially-scrambled, texture-based synthesized images (PS-synthesized images based on low-level texture information, and style-synthesized images based on high-level texture information). The results showed that 11 observers successfully classified natural scene categories with about 40 % accuracy for PS-synthesized images and with around 80 % for the style-synthesized images. These results suggest that high-level texture information is nearly sufficient for the recognition of natural scene category, while the low-level image statistics are not enough to describe it. Additionally, to reveal cortical dynamics of the natural scene perception, we recorded visual evoked potentials (VEPs) for the natural scene images, and analyzed the relationship between behavioral data and neural activities. As a result, we found that the VEPs within short latency (200 ms after the stimulus onset) successfully classified the natural scene category, and the representational similarity of VEPs and that of the behavioral responses were strongly correlated with each other. Taken together, the present results indicate that visual recognition of natural scenes largely depends on the global statistical information of natural scene images which are rapidly represented in the early visual cortex.
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Mapping idiosyncratic facial expression of emotion recognition: from eye movements to neural responses

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The study of individual differences in face processing has significantly gained interest in the last few years. It has recently been shown that the effective processing of identity involves both idiosyncratic visual strategies and idiosyncratic neural face representations. Nevertheless, whether such idiosyncrasies exist for other face processing tasks is unclear. While some studies have evidenced individual differences in the visual sampling of facial expression recognition (FER), none has explored yet their existence and consistency at the neural level. To this aim, we first tracked the eye movements of 65 observers during FER of the six basic facial expressions of emotion (FEE). With the use of data-driven statistical approaches, we isolated three visual sampling profiles characterized by a greater focus on the eyes, central nose, or mouth regions. We subsequently acquired the electrophysiological signals during the implicit categorization of the six basic FEE equalized for luminance and contrast with FPVS (fast periodic visual stimulation) on 30 among those participants – 10 per visual sampling profile. We recorded the neural responses, while fixation was enforced on the eyes, nose, or mouth regions. We found a significant correlation between the preferred fixated facial feature during FER and the FPVS neural responses to the same facial feature: the longer a face feature was fixated in FER, the more likely it was to elicit a stronger neural response when fixated during FPVS. Interestingly, the strength of the relationship was modulated by the FEE. Altogether, our data show that the effective processing of FEE involves visual and neural idiosyncratic representations, while this relationship is modulated by both the facial expression and the visual sampling profile. Overall, these findings reinforce the view that the neurofunctional processing of faces is not rooted in universal strategies and representations, even for the biologically relevant recognition of FEE.
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The Role of Cross-Area and Within-Area Temporal Correlations in Visual Segmentation

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The magnitude of temporal synchrony in visual attribute changes affects the strength of visual segregation across space. Specifically, two adjacent areas with multiple dynamic elements segregate perceptually when cross-area temporal correlation is low while within-area correlation is high. To gain insights into the underlying neural computation, we investigated how the segmentation performance is affected both by cross-area and within-area correlations. In our experiment, participants viewed a texture comprising Gaussian blobs with time-varying luminance, color contrasts, or Gabor patches with varying spatial phases. The temporal variation of the attribute followed a quasi-white noise with designated within- and cross-area correlations, where the areas implied the left and right halves of the rectangle texture. Correlations varied in nine steps (from 0.1 to 0.9 in terms of the absolute cosine similarity). There were 45 correlation pairs (cross-area correlation ≤ within-area correlation). We developed an algorithm utilizing Vision Transformer (ViT) to generate the texture stimuli with the intended correlation pair. Analysis of the generated textures indicated that the within- and cross-area correlations were close to the designated values, and the difference in low-level statistics between the two halves was negligible. The proportion correct for detecting texture segregation was measured for each correlation pair using the 2-IFC method. Results showed that the segmentation accuracy increased as the cross-area correlation decreased and the within-area correlation increased. The obtained psychometric functions could be explained well by a simple model where the proportion correct was a 1-D cumulative Gaussian function of Cd = [weight×(1–cross-area-correlation)+(1–weight)×within-area-correlation] (R^2 = 0.947, 0.919, 0.884 for luminance, color, and spatial phase, respectively). The threshold Cd for each attribute was 0.63, 0.642, and 0.74, while the weight was 0.43, 0.46, and 0.40, respectively. Our findings suggest that both within- and cross-area correlation directly influence segmentation and contribute nearly equally to the performance.
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Seeing speech: Probing the cerebral mechanisms of Cued Speech perception

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For many deaf people, lip-reading plays a major role in verbal communication. However, lip movements are by nature ambiguous, and do not allow for a full understanding of speech. Cued Speech was developed to complement lip-reading at the syllabic level with gestures resulting from the combination of a set of locations and shapes of the hand. The recipient thus has access to the entire phonological content of speech through the visual modality alone. Despite its proven efficiency, the mechanisms of Cued Speech perception remain largely unknown. The present study mainly aims at identifying the cerebral regions involved in Cued Speech perception and encoding its main components in expert and non-expert perceivers. To this end, we conducted an MRI study involving 3 groups of participants: Deaf and Hearing people proficient in Cued Speech and a group of hearing Controls naïve to Cued Speech. In Experiment I, participants were presented with silent sentences in Cued Speech, in lip-reading only, and with only the gestural part of Cued Speech. This allowed us to identify visual regions involved in the perception of full Cued Speech sentences: visual cortices identifying hand- and mouth- related cues, including early visual cortices, plus lateral occipital and fusiform regions. Among those regions, most were activated more strongly by the more salient gestures than by the more discreet lip-reading cues, but restricted sectors of the visual cortex had an opposite preference for lip-reading. Those activations had only subtle differences between groups. In Experiment II, we presented repeatedly 16 silent Cued Speech syllables resulting from the combination of 2 hand positions x 2 hand shapes x 2 points of articulation x 2 values of vocalic rounding. Decoding of those 4 features are currently conducted to determine whether each of the regions identified in Experiment I encode the corresponding phonological distinctions.
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Detection of visual field defects due to acquired brain injury with continuous visual stimulus tracking

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Accurate assessment of the visual field (VF) is essential in ophthalmic care and rehabilitation. Conventional VF testing (with standard automated perimetry) can be too demanding for some individuals. Continuous stimulus tracking has been proposed as an intuitive and fast alternative to conventional VF testing. Previously, we have shown that measured eye movements made during continuous stimulus tracking can be used to accurately detect and stage glaucomatous VF defects. The aim of this study was to examine whether it is similarly possible to detect VF defects due to acquired brain injury (ABI). Participants monocularly tracked a continuously moving stimulus (Goldmann size-III) at three contrast levels (40, 160, and 640%). We evaluated tracking performance (agreement between gaze and stimulus position) in 16 participants with homonymous VF defects due to ABI (eight with a left and eight with a right primary visual cortex lesion). We compared the data to previously collected data from 36 glaucoma patients and 36 controls. We found that the presence of a VF defect due to ABI decreased tracking performance compared to the controls. Strikingly, in cases of comparable visual field loss, the reduction in tracking performance in ABI was far less pronounced than the reduction observed in glaucoma. Furthermore, in ABI, tracking performance increased less with increasing contrast than it increased in glaucoma as ABI participants reached ceiling level tracking performance sooner. In conclusion, our findings show that VF defects in ABI lead to decreased tracking performance, but with a smaller decrease in ABI than in glaucoma. Differences in compensation of VF defects with eye movements between ABI and glaucoma or statokinetic dissociation (moving stimuli stimulate visual pathways that bypass the primary visual cortex and may thus be observed in apparently blind parts of the visual field) are possible explanations for this difference.

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Can we transfer what we know about efficiency of the visual system to AI algorithms?

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As AI applications become more pervasive across industries and individual users, and the computational demands of certain AI algorithms such as large-scale deep learning models have increased in recent years, reducing the energy consumption of AI is becoming a crucial concern. Energy consumption has played a significant role in shaping the evolution of sensory systems. Natural selection has favoured sensory adaptations that optimise energy efficiency while maintaining adequate perceptual abilities and information content, allowing organisms to effectively navigate and respond to their environments. The visual system is a major example of sensory system that has evolved to efficiently gather and process visual information while keeping energy consumption as low as possible. In this work, we first review the strategies employed by the visual system to efficiently process the torrent of information received by the retina. These strategies include sparse coding and other methods for redundancy reduction, as well as attentional mechanisms and predictive coding. We then examine how deep neural network models (DNNs) have integrated or could potentially integrate these strategies to reduce their computational demands. Specifically, we investigate whether spike coding, which differs from the continuous-valued activations typically used in DNNs, could enhance the energy efficiency of AI applications. We conclude that while vision science and neuroscience may inspire us to replicate the energy efficiency of the brain, achieving this goal will require specific software and greater imagination to translate the workings of biological systems into machines.
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The impact of changes in appearance and context on face learning

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Over the last decades, face learning was predominantly explained through the lens of the averaging hypothesis (Burton et al., 2005; Jenkins & Burton, 2011) originating from computer modelling (Kramer et al., 2018). This rationale suggests that transient variations are discounted whereas stable features are reinforced to construct a robust face representation over time. While this theory explains the advantage for the recognition of variable faces in lab-based face learning studies (Baker et al., 2017; Corpus & Orient, 2022; Ritchie & Burton, 2017) , it does not account for the demonstrated role of peripheral features in more ecological settings. Therefore, we have proposed a cost-efficient theory of face learning that postulates that face representations evolve following a coarse-to-fine prioritisation of facial information based on its relative stability over time. Following a similar parsimony principle, fixed learning contexts should foster coarse facial representations while changing contexts should encourage the identification of diagnostic facial features and a refinement of representations. To test these hypotheses, we designed a face learning experiment to check if variability of peripheral features and context lead to better recognition performance. First, participants learn eight women's faces with fixed or changing hairstyles, presented against fixed and changing scenes while their eye movements are recorded. Participants then perform a speeded old/new task and provide confidence ratings. These allow the calculation of area under ROC curves for each condition. Based on the cost-efficient theory, we predict that inner facial features of faces learned with varying hairstyles and/or contexts will be better recognized than faces with stable peripheral features and/or bound to a single context. Indeed, varying learning situations should yield the refinement of facial representations, unlike in stable learning conditions. We expect these effects to be associated with different ratios of fixations on faces and background scenes in the different learning conditions.

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Orientation tuning of face processing in human V1

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Human face processing is constrained by prior knowledge of natural face statistics, namely that faces typically appear upright, and as a strictly ordered alternation of contrast, best conveyed by horizontal morphological features. Using neuroimaging, we found that face-preferring regions like the fusiform face area (FFA) are selectively tuned to horizontal content of upright face information. Orientation selectivity is a fundamental characteristic of neural coding in the primary visual cortex (V1). This region is also shown to interact recurrently with high-level visual regions to refine visual representations. The present fMRI study investigates the orientation selectivity of face processing in V1 and ventral face-preferring cortex. To reveal the orientation selectivity for high-level and specialized processing of face shape, we compared intact (natural and contrast-negated) and phase-scrambled faces, filtered in restricted orientation bands (at 0°,30°,60°,90°,120°,150°). We measured mean univariate response to specific orientation ranges across stimulus classes. Preliminary results indicate that V1 orientation response profile follows a negatively-curved Gaussian dipping in the horizontal range. This horizontal attenuation was most prominent for natural compared to negated and scrambled faces despite equal oriented energy across conditions. Conversely, FFA responses for intact faces were highest at cardinal orientations. Moreover, multivoxel pattern analysis (MVPA) revealed that stimulus class significantly impacts decoding accuracy in both V1 and FFA. Orientation decoding was more accurate for intact than scrambled faces, with natural faces showing a cardinal advantage in both regions. V1 demonstrates higher orientation decoding accuracy for negated compared to natural faces. FFA shows the opposite pattern with the most severe decline in accuracy in the horizontal range with negation. These preliminary findings suggest that V1 orientation selectivity is influenced by stimulus properties presumably encoded at downstream processing stages. This supports the view of V1 as an active blackboard, updating its orientation-selective coding under the influence of higher-level visual regions.

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Extraction of optimally-informative features in fast vision: an ERPs study of C1 component

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It is widely recognized that, in fast vision, the visual system extracts the most relevant elements to create an early compact representation of the scene. Based on the assumption that visual saliency may be determined by maximum entropy criteria coupled with computational limitations, a recent model of early vision predicts a specific set of features as optimal information carriers, used to create this early saliency map. Psychophysical and eye movements studies demonstrated that these optimal features are considered more salient than other non-optimal, and they automatically attract attention. Considering the fast response timing of visual cortex's neurons and the similarity of their receptive fields with the spatial structure of predicted optimal features, V1 appears to be the most likely neural substrate for this map. To test this, we conducted an ERP study focusing on the C1 component, a reliable correlate of the earliest activation of V1, known to be modulated by selective attention. The task required to observe a compound containing a different percentage of optimal over non-optimal features (signal–to–noise ratios: 0%, 30%, 60%, 100%) while EEG was recorded. In a few random trials, a psychophysical task was introduced to measure individual preference for optimal features: one compound containing only non-optimal features (deemed non-salient stimulus) was presented simultaneously with another containing a variable number of optimal features (deemed salient stimulus), and participants were asked to choose "the most salient". Results show that C1 latency decreases as a function of stimulus SNR, in favor of the hypothesis that optimally-informative features get preferential treatment in fast vision, probably for their power in grabbing attention. Psychophysical results confirm optimal features to be perceived as more salient than non-optimal ones. Overall, our findings suggest that V1 may be the neural substrate responsible for computing efficient information compression under computational limitation constraints.

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Hypothalamic Syndrome Impairs the Recognition of Aversive Static Facial Expressions of Emotion

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The processing and recognition of aversive facial expressions of emotion relies on specific brain regions. Notably, in human healthy observers the insula is involved in a wide variety of functions ranging from aversive sensory to affective processing. However, how insular lesions impact emotion recognition abilities have led so far to contrasted findings. To further investigate this issue, we examined a single case of complex hypothalamic syndrome. Patient CE is a 38 years-old woman suffering from lesions in the right posterior insula, resulting from a haemorrhagic stroke caused by a congenital arteriovenous malformation in the temporo-insular and lenticulo-thalamic regions. We probed CE's ability to categorize the six basic static and dynamic facial expressions of emotion as well as the emotion of pain. A group of 40 age-matched participants served as a comparative baseline for CE's performance. Modified independent samples t-test developed for single case studies revealed a significant recognition impairment in the static condition for pain and disgust in CE compared to the AM controls. Crucially, however, in the dynamic condition CE's performance did not significantly differ from the AM controls. The right posterior Superior Temporal Sulcus (pSTS), which is spared in the patient, is functionally involved in social perception and dynamic biological motion. CE’s advantage for the recognition of aversive dynamic facial expressions of emotion might thus result from effective inputs and an intact functional pathway connecting the right pSTS to the insula. Altogether, our results provide new insights on the mechanisms of both the healthy and impaired emotion recognition system for the processing of aversive facial expressions. Additionally, they pave the way for innovative rehabilitation approaches exploiting the functionally preserved neural routes processing dynamic affective information. Crucially, our data also underscore the need to reassess the reliability of conclusions drawn from brain-damaged patients relying exclusively on static facial expressions.

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Selective Attention by Coherence Movement Unaffected by Auditory Divided Attention Strategy

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Sustained attention can be divided, i.e. the individual has to perform two tasks at the same time. When we are dealing with only visual or auditory sensory input, there is an increase in the activity of the modality-specific cortex, while there is a decrease in that which is not being specifically stimulated. Thus, when there is simultaneous visual and auditory stimulation, increases in activity in the sensory cortexes may be smaller due to processing limitations. For the research, we developed two tasks in which we prioritized local processing (High Spatial Frequency - HSF) and global processing (Low Spatial Frequency - LSF). In both tasks, we presented 150 radial sinusoidal gratings with a Gaussian envelope of three sizes: 10 (cycles per degree of visual angle - cpd), 5cpd and 0.5 cpd, which could move by 2º/s and 10º/s. In the baseline conditions, the results obtained were For the priority input stimulation of Global Processing, the average movement coherence threshold obtained for 2º/s (LSF2) was M=14.43, SD= 6.97 and for 10º (LSF10) was M=12.20, SD=3.75. On the other hand, the coherent movement threshold for input that prioritizes Local Processing, at speed 2º/s (HSF2) (M=13.22, SD=5.65) and for 10º/s (HSF10) M=13.48 (SD=5.08). In the divided attention experimental condition, the result was LSF2 M=20.96 (SD=11.84), LSF10 M=15.27 (SD=6.58). For HSF2, M=26.31 (SD=10.48) and HSF10 M=15.81 (SD=6.6). Even though the movement coherence thresholds were higher no significance was found (p> .05). We conclude that selective attention based on coherent motion thresholds already has a high attentional demand, reducing the effectiveness of the auditory attentional demands used.
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Abrupt Learning: How Does the Brain Decide What and When to Learn?

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Abrupt improvements in performance often occur following several unsuccessful attempts at a task, demonstrating that learning can be quickly engaged under the appropriate circumstances and retained over time. Studying these circumstances and their underlying mechanisms are important for our understanding of how the brain discerns optimal moments for acquiring and retaining new information. At present, these mechanisms are not well understood. We hypothesize that abrupt learning could manifest in at least two main ways: as a culmination of gradual latent learning reaching a threshold, or as an inherently abrupt learning event in itself. To examine our hypotheses, we conducted a visual foraging experiment with human participants, where they learned to locate hidden reward zones within naturalistic images through trial and error, using eye movements. Importantly, we halted the learning process for some images and evaluated participants' performance across all images the following day. The two hypotheses provide distinct predictions about the halting. According to the first hypothesis, when halting prevents abrupt learning, there will be a performance improvement for the same images on the following day due to latent learning. According to the second hypothesis, participants are expected to perform as naive observers on the following day. Our results supported the first hypothesis, revealing that participants performed a more informed visual search the following day, particularly for images where no learning behavior was observed on the initial day. Specifically, they avoided revisiting unrewarding locations from the initial day. Further insights into the potential mechanisms of latent and abrupt learning were gained through a thorough analysis of eye-tracking data. Subsequently, we tested these mechanisms using a reinforcement learning model. The integration of experimental findings and computational modeling affords a comprehensive understanding of mechanisms of abrupt learning within the visual foraging setting.

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Beating the iconic Arcade Game Pong – How Aging Impacts Predictive Gaze and Interception Performance

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To track and intercept a moving object, humans use eye and head movements to direct gaze at relevant positions that will foster associated body movements. If the moving object is tracked and its trajectory can be inferred, humans may predictively shift gaze to positions that are task-relevant in the future. Those predictive gaze shifts can compensate for sensorimotor processing delays. Due to naturally increased sensorimotor uncertainty and delays with aging, older adults may rely more on predictive gaze behavior in dynamic tasks. To investigate whether aging leads to greater reliance on predictive gaze when performing a sequential pursuing and interception task, we examined unconstrained gaze of younger and older adults while playing Pong. Participants competed against an artificial opponent in four randomly presented levels that differed in the underlying demands, from low (slow ball speed, large paddle) to high (fast ball speed, small paddle) difficulty. If aging leads to stronger reliance on predictive gaze, we should find earlier gaze shifts to future positions of interest (i.e. bouncing locations), which may be more pronounced when more precise visual guidance is needed (i.e. high task difficulty). Preliminary data show that both age groups intercept worse and increase saccades with greater task difficulty. The smaller paddle appears to elicit earlier gaze shifts to bouncing locations than the larger paddle, regardless of ball speed. Older adults appear to engage more head movements when the ball is approaching their paddle, compared to younger adults. Our results suggest that people shift gaze to positions of interest earlier when the task needs more precise visual control, possibly because this allows them to obtain relevant visual input earlier, but do not provide evidence that aging leads to earlier gaze shifts to those positions. However, head movements could be a strategy for older adults to reduce sensory uncertainty.
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Synesthetic Color Distribution in Color Space: Comparative Analysis among Grapheme-Color Synesthetes in Taiwan and Japan

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Studies on grapheme-color synesthesia have revealed that association between graphemes and their synesthetic colors are affected by various linguistic factors. Recently, Yang et al. (2024) compared Japanese and Taiwanese synesthetes in their associations between graphemes (Kanji or Chinese characters) and their synesthetic colors. They found common and distinct characteristics affecting grapheme-color mappings, indicating that linguistic characteristics of graphemes influence the synesthetic letter-color mapping in a language-specific manner. Previous studies also revealed that synesthetic colors themselves are not randomly distributed in chromaticity space but form clusters (Hamada, et al. 2016). Do linguistic factors also influence on the distribution of synesthetic colors in color space? The current study addressed this issue by comparing synesthetic color clusters between Japanese and Taiwanese synesthetes. Fourteen synesthetes (8 Taiwanese and 6 Japanese) identified their synesthetic colors using the Munsell color system for 179 Chinese characters or Kanji shared by Japanese and Taiwanese. Reported synesthetic colors were converted to CIE L*a*b* color space, and their spatial distribution was analyzed by L function. Spatial statistical analyses revealed that all synesthetes have clustered distributions. To clarify the relationship between color distributions of two synesthetes, cross-L function analysis can evaluate whether two distributions are independent, attractive, or repulsive. The cross-L function analysis revealed that regardless of native language, distributions of most synesthetic pairs were attractive, meaning that synesthetic color distributions have some basic similarities. To evaluate the distributional similarity more directly, we calculated Wasserstein distances between synesthetic color distributions. Again, regardless of the native language, there were no systematic differences in distributional similarities between Japanese and Taiwanese synesthetes. These results suggest that sampling of synesthetic colors from color space and clustering in their distribution are not modulated by linguistic factors and may be universal characteristics of grapheme-color synesthesia.
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Combination of eye-tracking and performance data to extract situational awareness profiles.

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Since 2010, the number of fatal accidents at work in Europe has remained above a glass floor of 3200 deaths a year. The nature and causes of these accidents are varied (falls, road accidents, illnesses, etc.) but result, in 80% of cases, from dysfunctions in the "human factor". The "human factor" includes all non-technical skills: situation awareness, decision-making, communication, teamwork, leadership, stress management and fatigue management. More specifically, situation awareness is the ability to know what is happening in one's environment in a given situation. It consists of three stages: (1) perception of the spatio-temporal elements of the situation; (2) understanding of the elements and the situation; and (3) projection of these elements into the future situation. Several studies used eye-tracking measurements to quantitatively measured situation awareness with duration fixation, number of visits, number of fixations and spatial exploration. The goal of this study is to characterize situation awareness, in the form of behavioral profiles, on the basis of eye-tracking and performance data using k-means unsupervised clustering algorithm and linear discriminant analysis. For this purpose, we use an interactive planning and resource allocation task, called “Water Purification Plant”. During this task, we collect several eye-tracking and performance indicators to characterize situation awareness. Our preliminary results on 23 participants showed the presence of two

different behavioral profiles for situation awareness. The “high” situational awareness profile is mainly characterized by good performance on the task due to higher spatial exploration of the scene. Moreover, this profile differs from the “low” situational awareness profile by a lower number and duration of fixation. The eye-tracking pattern in the case of good situational awareness would be more refocused on the areas of interest necessary for the proper execution of the task, with a more global and controlled exploration of the scene.
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Representations of unfamiliar objects before and after movement

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Visual objects in the human brain are represented along an animacy continuum, where objects that are more animate (e.g. humans) are placed on one end of the spectrum, and objects that are less animate (e.g. a lemon) are placed on the other. This spectrum has been explored in terms of agency, humanness, predictability, face-body divisions, capacity for movement and more. Despite animacy, predictability and movement potentially playing a significant role in object representations, this topic has predominantly been studied using static images, neglecting the dynamic aspects that contribute to how objects are represented in relation to one another. In this study, we include video stimuli to investigate how motion influences the perception of animacy and agency in familiar and unfamiliar objects. Specifically, we employ robots as novel objects that sit on the animate-inanimate border and are shape matched to biological counterparts that fall along the animacy spectrum. Novel objects are capable of self-initiated movement, with both fast and slow dynamics, and we include two control cases of objects being moved by external forces. Thus, our experiment has 3 shape-matched conditions: biological, fast unfamiliar and slow unfamiliar. We assess properties of perceived intelligence and agency of these novel objects using the Meadows platform, before and after watching videos of the objects in motion (n=20). Given that participants have had little to no exposure of viewing these unfamiliar objects prior to video watching, our results relate to predictive coding principles, where the representation of objects is influenced by how we expect them to move. Our results shed light on how we represent embodied artificial agents along the animacy spectrum. Furthermore, we discover the interaction between the shape and motion dynamics of unfamiliar objects in how they are perceived in relation to one another.
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Visual field position and familiarity effects under interocular suppression

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Our brain reacts differently to visual stimuli of different patterns or presented at different retinal locations. Previous studies suggested that, in standard viewing conditions, visual perception varied depending on visual hemifields. However, under interocular suppression, the influence of position on visual performance is unclear.In this study, we used Continuous Flash Suppression (CFS) to allow for a more comprehensive comparison of visual field performance. Additionally, we compared the competitive advantage of stimulus familiarity. Experiment 1 adopted breaking Continuous Flash Suppression (b-CFS) to compare response times (RTs) of targets (familiar/unfamiliar icons) at nine positions in the visual field, compared to baseline (no-CFS). Experiment 2 combined CFS with a discrimination task and adopted EOG to further investigate perceptual processing. Results were largely consistent across the two experiments. RTs for targets in the nasal visual field were consistently faster than those in the temporal hemifield. Targets located on the horizontal meridian demonstrated better visual performance compared to the vertical meridian. Also, an advantage in the upper visual field on the vertical meridian was observed. Additionally, we found that the detection of familiar targets was faster compared to unfamiliar targets. Interestingly, while the horizontal and vertical meridians exhibited superior visual performance in the discrimination task, we observed the opposite pattern in the b-CFS task. Generally, under CFS the advantage of the center position was diminished. These findings indicate that the positional competition mechanism under interocular suppression differs from standard viewing conditions. Interocular suppression introduced asymmetry in nasal-temporal hemifields, while differences in other visual field positions were reduced. For stimulus familiarity, the perceptual advantage for familiar targets may be attributed to enhanced processing in the unconscious stage. Therefore, it is crucial to characterize positional biases under interocular suppression to control unwanted effects and minimize their impact on result interpretation.

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How Exposure to Diverse Faces Shapes the Computational Mechanism of Face Perception

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Despite humans' proficiency in recognizing faces, they often face difficulties when identifying faces from races less familiar to them, a phenomenon known as the Other-Race Effect (ORE). Although extensively studied, the computational mechanisms underlying this phenomenon remain elusive. Here, we use deep convolutional neural networks (CNNs) to investigate how racially varied facial exposure affects the networks’ feature processing and alignment with human face perception behavior. We trained three CNNs: one exclusively on white faces, another exclusively on Asian faces, and a Dual CNN on both. Consistent with prior research, single-trained CNNs exhibited an ORE, showing decreased performance on untrained races. Intriguingly, the Dual CNN performed well on both races, outperforming the single-trained CNNs. This indicates that diverse training mitigates CNNs’ ORE – a finding paralleled in human development. To directly assess these findings’ relevance to human behavior, we evaluated the consistency between CNN decisions and those of Asian and white participants in a triplet matching task. The Dual CNN best aligned with the behavioral choices across all participants, despite their own

ORE, suggesting that diverse training equips CNNs with a broader, more generalized understanding of facial features across races. Further analysis of the CNNs' feature processing revealed that, unlike the single-trained networks which showed race-specific representations, the Dual network showed a unified representational space for all faces. To explore this integrated feature space's generalizability, we tested all CNNs on an entirely unfamiliar race, black faces, and found that the Dual CNN again outperformed single-trained CNNs. This finding offers testable hypotheses on the impact of diverse facial exposure on human cognition. Overall, our results show that training on diverse datasets not only mitigates inherent biases in CNNs but also aligns them more closely with human behavior, thereby providing a stepping stone towards a computational understanding of the ORE in humans.
Acknowledgements: This work was supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)-project number 222641018-SFB/TRR 135 TP C9, "The Adaptive Mind", funded by the Excellence Program of the Hessian Ministry of Higher Education, Science, Research and Art, and the European Research Council (ERC Starting Grant DEEPFUNC, ERC-2023-STG-101117441).

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Capturing Aesthetic Experience by verbal expressions:

Identifying core concept variables from natural language processing

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A fundamental challenge for aesthetic research, independently of the sensory domain (e.g., visual, haptic, acoustical), is to capture aesthetic experience in an adequate way. A series of questionnaires, scales, and inventories exist, but they are mostly based on the intuitive thinking and beliefs of single researchers. Here, we offer a data-driven approach that utilises the Python Natural Language Processing (NLP) library, out of which we generated a corpus with "Syntems" as its foundational vocabulary units. This was followed by employing the Sentence Transformer library to calculate multidimensional embeddings, thereby establishing a semantic representation of words across various contexts. These embeddings encapsulated the meanings of words by positioning them within a high-dimensional space. Words with semantic similarities converged within this space, aiding in concept delineation. Subsequently, we assessed cosine similarity (range 0 to 1) between the embeddings of approximately 20,000 words and the term "visual", "haptics," etc., refining our dataset to 1,000 words indicative of significant relevance for the specific sensory domain. Leveraging the UMAP (Uniform Manifold Approximation and Projection) machine learning algorithm, we projected these embeddings from the high-dimensional space to a 2D plane, preserving their relative proximities to visualise semantic relationships. Despite the utility of the aforementioned approach, it exhibited notable limitations: The 2D projection stability is questionable, as minor alterations in the data points can yield significantly different visual representations, undermining the reproducibility of the semantic maps. Additionally, the specificity of embeddings—crucial for elucidating well-defined constructs—required further refinement to enhance their discriminative capability and group delineation. Despite these limitations, we can offer a tool that is capable of producing comprehensive lexicons, specifically for certain sensory modalities, different application areas and addressing language-specific linguistic descriptions. As such it can be a highly valuable tool for establishing more comprehensive, fine-attenuated and highly specific inventories.

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Computational mechanisms underlying contextual and structural biases in time perception

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Time is a fundamental aspect of perception but is also surprisingly highly variable across individuals: time perception depends on both idiosyncratic traits and environmental adaptation processes. Distinguishing these two sources of bias allows us to dissociate the predictive mechanisms that generate them. These structural and contextual biases have been observed separately, but their interaction has not been quantified. Our goal is to study how structural constraints and adaptive mechanisms interact in the perception of time in healthy participants. We quantified precisely the structural and contextual biases in a duration discrimination task to constrain models of duration perception. Following the presentation of two consecutive stimuli, participants had to judge which one lasted the longest. The stimuli were either both visual, both auditory or one from each modality. Confirming previous reports, a sound was often perceived longer than a visual flash of the same duration, a bias that probably reflects intrinsic properties of audiovisual neural processing. This bias was variable across individuals but stable within an individual, thereby reflecting structural constraints. Contextual biases were manipulated using two duration distributions, that is known to modulate the perception of a given duration. Each of the two durations to compare came from different distributions (short/long or long/short). Bayesian models are typically used to explain contextual effects in estimating duration, such as regression to the mean. Another mechanism, leading to opposite predictions, is based on recalibration: after repeated exposure to a constant lag, the perceptual system is able to correct for this lag and shift the perception of subsequent durations. Preliminary results show that participants' responses are mostly driven by recalibration processes rather than Bayesian adaptation. These results challenge existing literature on contextual effects in duration perception and suggests that the brain operates some normalization to represent durations.
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Influence of Aging on Vection

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We might feel as if we are moving in the opposite direction to what is moving around us, even though we are standing still. This phenomenon is called "vection" (self-motion perception). It is known that the latency of vection tends to be shorter in the elderly in younger people (Lestienne et al, 1977; Lich & Bremmer, 2014). In addition, the center-of-gravity sway during the observation of vection is larger in the elderly than in the young, but the vection rating is low (Haibach et al, 2009). Recently, it has been reported that the center-of-gravity sway is larger in the elderly than in the young, but there is no difference between them(Kenney et al, 2021). The present study examined the integration between visual and vestibular senses during vection occurrence in the elderly using video images similar to real-life situations. In Experiment 1, multiple images using four 75-inch monitors, intensity of the vection generated from viewing two, three or four of front, floor, right and left monitors. We found that vection occurred faster in the elderly than in the younger subjects. In Experiment 2, a single screen presented the video images, and we compared the strength of vection between the standing and seated conditions. The results showed that there were no significant differences between the elderly and younger participants in both the posture and presentation location conditions. These results confirmed that the magnitude of center of gravity sway does not affect vection in elderly as well as younger participants. When stimuli were presented at multiple monitors, vection occurred faster than younger participants in the elderly. These characteristics suggest that the elderly are less likely to establish independence of sensory aspects.

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Target-irrelevant features can affect behaviour in a visual foraging paradigm

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Visual foraging is a task in which participants search for multiple instances of targets in the environment. In one popular paradigm, participants are tasked with finding all exemplars of two different classes of targets on a 2D display. Previous research has shown that behaviour in this task can be affected by the difficulty of the search and the value assigned to the targets. Our recent modelling work has also shown that spatial factors can strongly affect behaviour, with participants preferentially selecting nearby targets. Here, we show that behaviour can also be affected by task-irrelevant features of the display. In a first experiment, participants carried out classic conjunction foraging trials, but on some trials, a white line was added to the display, either spanning the entire vertical midline or the horizontal midline. We find that participant strategies are affected by these irrelevant features, with participants selecting targets in an order that reduces the number of times they cross the line compared to a control condition without any lines present. We further investigated this effect in a second experiment, with two levels of difficulty: easy trials where targets were distinguished by one feature (colour) and difficult trials where the target was defined by the conjunction of two features (colour and shape). The target array could also have three different configurations: cardinal (a 'standard' grid array), rotated (a grid array rotated by 45 degrees) or uniform random. Finally, some trials had a task-irrelevant feature (a vertical white midline) added to the display. We again find avoidance of the line, regardless of spatial structure or task difficulty. Our findings suggest participants may use the line to split the stimulus into two 'patches', and may help to link work on modelling target-by-target behaviour in visual foraging with the literature on optimal patch leaving behaviour.

Symposium 5 - Gaze patterns in natural behaviour

Age-related changes in eye movements during manual tasks

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Humans use their vision to plan and control their body movements. They can continuously shift their gaze to scan for relevant information in the environment or direct and maintain their gaze to specific positions even before the relevant visual information appears in those areas of interest. While the former can help obtain visual input from larger parts of the environment, the latter predictive gaze shifts can help circumvent delays in visual processing, and poorer peripheral vision, and reduce costs associated with eye movements. As aging is associated with compromised sensory and motor processes, we examine whether older adults rely more on predictive gaze when performing visuomotor tasks. Young and older participants reached to hit a visual target that appeared at a position that was either predictable, somewhat predictable, or chosen randomly in each trial. Gaze was shifted earlier towards more predictable targets, but older adults did not appear to rely more on predictive gaze than younger adults. We then asked participants to reach and hit a central target that would jump to a lateral position upon hand movement initiation. This new position was again predictable, somewhat predictable, or random. Again, participants shifted their gaze to the new position earlier when that position could be deduced. Contrary to the previous experiment, older adults demonstrated earlier predictive gaze shifts than younger participants. In a third study, where participants intercepted a moving target at a predetermined hit area, older adults looked at the hit area earlier than younger adults, and they did so well before the target arrived there. We show that aging does not necessarily lead to predictive gaze allocation when planning and controlling arm movements. Rather, gaze can be predictively allocated when the underlying circumstances make it advantageous to circumvent reliance on online vision.
Acknowledgements: This work was supported by the German Research Foundation (DFG) under grant agreement VO 2542/1-1.

Coordination of bimanual movements when acting on separate objects is shaped by competition for gaze

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When performing real-world manipulation tasks, such as cooking, our two hands grasp, move, and place multiple objects in variable locations. In such tasks, objects that are manipulated by each hand may become available (or relevant) at different times during the unfolding action. We designed a task in which participants used their left and right hands to independently grasp objects at separate

start locations. Each object was dropped in respective slots located to the left and right of the midline. After an object was dropped, a new object appeared at the corresponding start location. Left objects always appeared 0.5 s after a left drop, and right object reappearance varied, across trials, from 0.5 to 3.5 seconds. The left hand was free to continue to move while the right hand awaited a new object. Each trial lasted 40 s and participants received points for object drops. We found that participants consistently fixated manipulation events, with gaze being at object grasp in 92% and object drop-off in 95% of all events. When both objects were available shortly after each drop, participants subsequently fixated each start position during grasp before shifting gaze to each object drop-off. In these trials, participants moved their two hands together—with a 1:1 left:right movement ratio—but with a flexible temporal offset. As the right object delay increased, the probability of fixating and moving the left object alone gradually increased towards a 2:1 left:right movement ratio. In general, the temporal coordination between the hands was highly flexible and not constrained to fixed movement ratios within a trial. This seemingly complex pattern of hand coordination could be explained by a model that optimized reward and included competition for gaze resources (requiring gaze to be directed to each object as it was grasped and each slot as an object was dropped).
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Exploring everyday actions: Gaze behaviour during stair climbing

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In daily life, an interesting situation arises when a task does not impose a certain gaze strategy, but does benefit from visual guidance. An example of such a task is stair climbing. I will first describe some new measures to quantify where people look when climbing staircases. Exploiting these measures revealed that there is a lot of variability across participants in terms of where they look, including variability in the number of fixated steps. Despite such variability, there are clear differences between where participants looked when climbing stairs in a familiar setting compared to when doing so in laboratory settings, including a systematic tendency to fixate fewer steps. We also found that participants fixated more steps and looked around less when explicitly asked to navigate a staircase than when they navigated the same staircase within the context of a longer task that involved navigating the staircase, but in which the staircase was not explicitly mentioned. Delving further into the observed variability across participants in the number of fixated steps, we showed that at least part of the variability could be attributed to highly idiosyncratic gaze strategies. This is revealed by the correlations between participants' fractions of fixated steps across different conditions, such as when ascending or descending the staircase, when climbing with or without a tray, and when climbing with or without another person in front of them. The large, systematic variability across participants suggests that evaluating individual differences might be essential for really understanding the allocation of gaze in everyday actions.

On the role of eye and head movements for walk transitions in real world scenes

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Human gaze behavior plays a significant role for successful goal-directed locomotion. Yet, it has been rarely employed in multimodal models for predicting real-world human walk behavior. In this study, we set out to investigate its potential for improving the prediction of upcoming walk mode transitions in real-world urban scenes. We use a publicly available data set including IMU motion data and gaze data from the Pupil Labs Invisible eye tracker. 20 participants completed 3 laps of an urban outdoor walking track including 3 types of walk modes: level walking, stairs (up, down) and ramps (up, down). In line with previous work, we found that participants direct their gaze (vertical eye and head angle) more strongly towards the ground during more challenging transitions. Moreover, participants adjust their gaze behavior prior to adjusting their gait behavior. Thus, we trained a random forest classifier for predicting walk mode transitions based on either gaze or gait parameters or on the combination of the two. Results show that more challenging transitions involving stairs are easier to predict and that combining gaze and gait parameters leads to the most reliable results. However, gaze parameters had a greater impact on classification accuracies compared to gait parameters in almost all scenarios. While accuracies for correctly predicting a transition drop as a function of the forecasting horizon (1 to 4 steps ahead), we still find an average classification accuracy of 60% based on gaze and gait data, for predicting a transition from walking to either stairs up or down, 4 steps ahead in time. Taken together, our results suggest that gaze behavior changes in anticipation of an upcoming walk transition and as a function of the expected challenge for balance control. Consequently, we show that it can significantly improve the prediction of walk mode transitions for real-world gait behavior.

Gaze Strategies in High-speed Racing

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When we move in 3D space, active gaze usually determines when, from where, and for how long visual information gets sampled. In the skilled performance of experts, such as elite athletes, specific gaze strategies are found to support the exceptional perceptual-cognitive skills. Eye tracking can be combined with performance analysis to gain insight into how gaze contributes to perceptual-cognitive organization of such performance. This in turn can deliver insights into the underlying visuomotor, attentional and memory abilities, beyond what can be gleaned from simplified laboratory experiments. For example, in the case of a racing driver taking bends at speeds up to 200-300 kph the perceptual-cognitive system and motor coordination are pushed to the limits, and task performance likely depends critically on timely gaze coordination. I will present as a case study measurement and analysis of the eye movements of a professional racing driver a high-grade industrial racing simulator. I will introduce a novel analysis concept (Gaze Keypoint events and locations) which was used to combine eye, head, telemetry and localization data for visualization and analysis, and show how gaze (i.e. eye and head) coordination is embedded within the unfolding skilled action sequence, with a striking consistency. I then discuss how the method and results extend existing work on expert gaze strategies in sports, what they inform us about the underlying perceptual-cognitive processes, and how they can point to new ways of analyzing and interpreting active gaze data in the wild.

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Talk Session 9 - Objects & Scene Perception

Mapping Neural Activity During Free Viewing with Concurrent MEG and Eye Movement Recordings

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Eye movements are essential for most daily tasks, from reading a book to driving. While a lot is known about eye movement patterns and behaviour underlying real-world tasks, the understanding of the underlying neural mechanisms is much more limited. One crucial reason for this is that eye movements produce artefacts in the electrophysiological (M-EEG) recordings that are larger than the brain signals. Here, we present a novel approach to analyse concurrent MEG and eye tracking recordings. We first show how we can identify and characterise robust markers of saccadic spike artefacts in the time domain and in the frequency domain. By applying source modelling to saccade and fixation aligned data, we found a strong lambda response appearing around 100ms after fixation onset, which is localised in the primary visual cortex. We used this approach to investigate the neural underpinning of hybrid search, where observers search for any of several possible targets. The analysis of fixation-aligned evoked responses allowed us to identify a robust target-related component, consistent with the P3 component frequently observed in target-detection tasks. A time-frequency analysis performed across the whole task allowed us to study the signal power changes when memorising, retaining, and searching for an object. We found a significant occipito-parietal power decrease in the Alpha band (8-12 Hz) activity, which was modulated by memory load. Finally, a connectivity analysis led us to observe the emergence of a visual network during visual search. Altogether, our approach offers a way to investigate neural processes under conditions that are close to real-world situations.
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Assessing the role of inter-object relations in visual cortical responses to natural scenes

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Real-world scenes are more than collections of objects: they also involve relations between them. A scene with a chair under a table is substantially different from a scene with a chair on top of a table, and this difference can be readily perceived. Whether inter-object relations are explicitly encoded in the human visual system, similarly to the identity of individual objects, remains an open question. Here, we take advantage of a large-scale fMRI dataset of human subjects viewing richly annotated natural images (~3000 images/subject). This dataset includes explicit labels of both the objects present in each image, and relations between them. By directly fitting these labels to the fMRI data using voxel-wise linear encoding, we find that relations explain no unique variance, with most variance shared between objects and relations, and some unique to objects. This result holds both when object and relation labels are encoded as binary vectors and as language model embeddings. We additionally test whether multiplicatively binding object labels with their roles within a relation (agent or patient), a classic connectionist method for encoding relational information, improves their fit to the data. On the contrary, we find that multiplicative binding reduces the fit compared to simply summing up all the labels. However, in apparent contradiction to these results, and consistently with previous findings, we find that language model embeddings of full scene descriptions can fit the fMRI data better than all other representations, indicating that representations in the visual system are not limited to mere collections of object identities. Together, these results suggest that inter-object relations are not represented explicitly and independently of object identities in the human visual system. On the other hand, richer scene descriptions do provide additional predictive power, raising the possibility that relational information might be represented in a more implicit format.

Understanding the time course and spatial biases of natural scene segmentation

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Segmenting visual stimuli into distinct visual objects is central to visual function, but the computational logic and temporal dynamics of human perceptual segmentation of natural stimuli remain unclear. To address these questions, we developed a novel paradigm to measure perceptual segmentation maps of natural images and videos. The dominant view is that perceptual grouping is a time-consuming process, because it requires recurrent interactions between visual-cortical neurons. This conceptual model predicts that, due to retinotopy in visual cortex, judging if two regions of an image are grouped takes longer if they are more distant, because signals need to travel between neurons that are farther apart in visual cortical space. Surprisingly, we find that spatial proximity does not predict the time-course of segmentation: reaction times increase with distance when two regions are perceived in the same group, but decrease with distance otherwise. We hypothesize that this may reflect spatial proximity biases, namely a preference to group together items that are close in visual space, and that perceptual decisions take longer when the visual input is incompatible with the bias. Although proximity biases are well established in traditional psychophysics, the evidence in natural vision is anecdotal. Here we provide the first characterization of spatial biases in perceptual grouping of natural images. Next, to test our hypothesis, we develop extensions of the Drift-Diffusion Model (DDM) of evidence accumulation, to model the effects of spatial biases as a Bayesian prior. Fits to reaction time data and quantitative model comparison show that the interaction between spatial biases and dynamic evidence accumulation is necessary to explain our findings, with important implications for neural mechanisms.
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Bedazzled by dazzle camouflage? A new experiment, and critical reappraisal of a 105-year-old data set

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In WWI, dazzle camouflage involved painting allied shipping with bold geometric patterns to disrupt the perceptions of enemy submarine captains. Only two publicly accessible quantitative studies have investigated this directly, both involving perceptual judgements of target ships under various treatments. The first experiment (Blodgett, 1919, MIT Libraries, MA) used mechanical simulation and models, whereas the second (e.g., Meese, Lovell & Sharman., 2022, Perception, 51(5), 354-) used online computer displays. Blodgett reported perceptual direction errors (~60 deg) ≥ twice the magnitude of corresponding results in Meese et al. and, unlike them, concluded that dazzle was highly beneficial. A declassified American naval document (Bittinger & Hulburt, 1936, FR-1302) came to similar qualitative conclusions as Blodgett. To resolve this conflict, we reappraised Blodgett's work. First, we uncovered three categories of mistakes in his analysis: arithmetic (differencing and averaging), misidentifications of bow/stern, and distortions of central tendency by averaging absolute instead of signed errors. With these issues addressed, the misperceptions aligned across studies. Second, we found that unbeknownst to him, Blodgett's results implied that the major perceptual component owed to hysteresis—a tendency for perceived direction to parallel the horizon (Meese et al)—with dazzle accounting for only a modest twist effect of ~7 deg, which diminishes the protective benefit of hysteresis as much as enhancing it. However, unlike Meese et al, Blodgett reported much smaller effects for ships without dazzle, but for unspecified participants and conditions. To investigate this mystery, we image-processed Blodgett's ship photographs to grey and in computer-controlled experimentation found similar hysteresis effects for ships with and without dazzle. Finally, our analysis of Blodgett found no effects for observer, colour/pattern, class of ship, or skyscape. We conclude that experiments run over 100-years apart are consistent after all, and contrary to American beliefs, wartime dazzle provided only modest protection by perceptual distortion of heading.

The role of executive functions in organized foraging

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Visual foraging involves searching for multiple targets among multiple distractors, allowing for investigation into how visual attention is oriented over time, as well as how target search is organized throughout a trial. Few studies have looked into the organizational abilities of children and healthy adults, but organization has been shown to increase linearly from age two up until adulthood. An interesting question that remains unanswered is whether organizational abilities are in any way connected to executive functions, which are a complex network of cognitive processes that underlie our ability to control our thoughts and behavior and are believed to be connected to attentional orienting. Some researchers seem to equate organization and executive functions, while others claim these are completely separate functions. In the current study, five age groups, children aged 6, 9, 12, and 15, and adults (combined N = 86), completed feature and conjunction foraging tasks, as well as a test battery assessing executive functions. Four measures of organizational abilities were calculated; best-r, number of intersections, mean inter-target distance, and deviation from the optimal path. Various tasks were used to assess four subdomains of executive functions; inhibition, attentional flexibility, working memory, and planning. No connection was found between organizational performance in the easier feature foraging task and executive functions. In the more demanding conjunction foraging task, there was however a connection between three measures of executive functions; inhibition, attentional flexibility, and working memory, and both target distance and deviation from optimal path, as well as between working memory and number of intersections. When foraging tasks become complex and attentionally demanding, higher levels of executive functional abilities seem to facilitate more organized search patterns.

A new psychophysiological method to assess automatic visual processing of task-irrelevant global and local shapes

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Visual perception involves the processing of both global (whole) and local (detailed) information. While conventional methods focus on the voluntary visual processing of global or local information when they are task-relevant, the method for investigating the automatic visual processing of global and local information when they are task-irrelevant is not established. This study proposes a novel psychophysiological method to investigate automatic visual processing of global and local shapes. We employed compounded figures, comprising a larger global geometrical shape composed of multiple smaller local geometrical shapes. Participants viewed visual stimulus sequences; an infrequent nontarget stimulus (deviant) was inserted in a repetitive presentation of frequent nontarget stimulus (standard). The standard and deviant could be different on either the global or local shapes only. Additionally, a stimulus which is different from the standard and deviant in luminance (target) was also inserted. Participants were asked to give a response to the target but not the standard and deviant. Hence, the global or local changes between standard and deviant were task-irrelevant, which allowed us to separately investigate the effects of task-irrelevant global and local processing. To extract brain activities related to the global and local changes, we measured electroencephalogram when participants viewed the stimulus sequences and extracted an event-related potential (ERP) effect which is known to reflect automatic visual global and local change processing: the visual mismatch negativity (MMN). Our results demonstrated the significant presence of visual MMN for both local and global changes. We also observed a systematic difference between global and local changes in the visual MMN. Hence, we achieved a successful measurement of brain activities that are specifically related to automatic visual processing for task-irrelevant global and local changes. This proposed method provides powerful tool to investigate the mechanisms of the automatic global and local processing.

Symposium 6 - Reproducing reality: What is needed to build displays that pass the "visual Turing test"?

Building displays that reproduce reality: why it is straightforward in principle but difficult in practice

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A long-standing challenge in visual displays is to generate imagery that is sufficiently realistic to be indistinguishable from viewing the real world. In principle, this could be achieved by reproducing the light-field at the eye, described by the 4-D plenoptic function. In practice, it requires a display that can present the full range of relevant dimensions—spatial resolution, dynamic range, colour gamut, and depth-related cues—with sufficient fidelity. We address this by combining several existing display approaches, each intended to address specific shortcomings, into a novel multiple-focal-planes, high-dynamic-range stereoscopic display. A key feature of our approach is the capability to switch the observer's view between seeing the display and seeing an equivalent real scene in the same location. This allows us to directly administer the so-called Visual Turing Test, by asking observers to discriminate real from displayed scenes using a three-alternative, forced-choice (i.e. oddity) task. Presenting focus cues correctly is particularly challenging, and our work here highlights several more general issues in understanding the requirements for a display to pass the Visual Turing Test. First, an apparent lack of contribution of a given visual signal can easily be confused with implementation-specific shortcomings in a particular display, especially where our understanding of signals remains incomplete. Second, both the capability of displays to present certain visual signals correctly, and the importance of those signals to perceptual realism, can be dependent on the content of the depicted scene. This makes it difficult to draw general conclusions about either the contribution of signals or display efficacy. Finally, improving fidelity of one display property often requires trading-off another. It is important therefore to understand whether hard-to-get-right signals must, individually, be indiscriminable from their real-world equivalents, or whether (similar to sensory cue-integration) shortcomings can instead be compensated for by high fidelity in other signals.
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Reproducing accurate colour in high dynamic range

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In high dynamic range (HDR) imaging, the question of replicating human colour perception poses a considerable challenge. HDR imaging seeks to cover a broader range of luminance levels than traditional imaging systems, aiming to mimic the wide and highly adaptive dynamic range of the human visual system. Advancements in HDR technology have led to displays that can produce brighter and more vibrant images, extending up to 5,000 cd/m2. This leap forward introduces calibration challenges, particularly because HDR displays showcase a much wider range of colours than their standard dynamic range (SDR) counterparts. Accurate calibration of HDR monitors is essential to ensure the expanded colour gamut is reproduced faithfully. However, this process is hampered by the lack of consensus on industry standards, making it difficult for perceptually accurate colour reproduction. In a recent work, we showed the difficulties involved with calibrating HDR OLED displays especially when manufacturers used their own non-standard tone-mapping curves and colour space transformations to reproduce colours within their own display's capabilities but which are not necessarily accurate radiometrically. Another challenge associated with colour imaging in the high dynamic range is the lack of colour difference metrics that span a wide range of luminance levels. We proposed the introduction of rod responses in addition to cone responses in different colour difference formulae to account for colour perception differences between mesopic and photopic light levels. Ensuring that HDR displays can accurately reproduce realistic colours, in a way that aligns with human visual processing, requires ongoing research and innovation in both display technology and vision science.
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Immersive reality: effects and uses of VR in perception

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Virtual reality (VR) has proven to be an excellent sandbox for studying visual perception. User studies carried out in VR are safe, cost-efficient, easily reproducible and provide complete control over the visual information that the participants receive, ensuring a high degree of experimental control that is difficult to achieve in the natural world. Numerous vision science experiments have been successfully replicated in VR, delineating the domains in which visual behavior is equivalent under the influence of this new immersive medium. Meanwhile, computer graphics researchers strive to achieve as much realism as possible for VR head mounted displays. The pursuit of realism within VR raises profound questions about the limits of technology and the nature of human perception. How close are we to creating virtual experiences that are indistinguishable from reality? And what methodologies can we employ to correctly measure human perception and visual behavior? Addressing these questions, we will delve into three case studies within the VR field: (1) how to measure and isolate high-level cognitive aspects of human behavior; (2) the pivotal role of context and cognitive frameworks in shaping visual perception and (3) why considering additional modalities in our frameworks is necessary when studying visual perception. By unraveling the perceptual shortcuts employed by theth brain to construct a unified notion of the surrounding environment and examining its flexibility in adapting to new forms of sensory input, we can identify which aspects of sensory information are crucial for crafting convincing virtual experiences. This knowledge, in turn, will direct the focus of future research towards addressing the most significant perceptual challenges faced by VR users. Ultimately, adopting a user-centric approach in VR research will enhance our ability to pass the Visual Turing Test, creating experiences that are indistinguishable from reality for the user.
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The value of synthetic image statistics for understanding the structure and perception of natural scenes

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The Visual Turing test for displays assesses the degree to which they deliver visual experiences that are indistinguishable from reality. The difficulty of this challenge is influenced by the complexity of the scene that is depicted. For example, an image of a simple texture on a planar surface, viewed monocularly by a static observer, will be more difficult to discriminate from reality than a complex 3D structure, viewed binocularly by a freely-moving observer. The dimensions of reality, complexity, and naturalism are all important in defining the degree to which displayed images recreate our experience of the physical environment. The technologies of 3D scanning and rendering are of great value for exploring these dimensions. 3D scans allow us to accurately capture the shape of objects at very fine spatial scales. 3D rendering techniques allow us to generate photorealistic images of scenes combining scanned and artificial objects. A critical feature of this approach to creating visual stimuli is that it provides accurate, multi-dimensional ground truth. Thus, for every pixel, we know not only its colour, but also the 3D location of the corresponding point in the virtual environment, the object that it belongs to, the material properties of that object, and the prevailing lighting conditions. Through a series of examples, we show (1) that images can be rendered that have the luminance and depth statistics of natural scenes (2) how these can be used to understand our perception of 3D shape across multiple spatial scales and (3) how ground truth information can be used to understand the origins of many of the statistical regularities found in natural scenes.

Setting requirements to reproduce reality: A controllable AR/VR headset simulator for active observer psychophysics

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Realistic, immersive virtual and augmented reality (AR/VR) requires accurate user tracking to enable perspective-correct rendering. Similarly, a cost- and space-efficient stereoscopic display to present these images to users requires near-eye optics for compact form-factor head-mounted displays (HMDs). Modern-day HMDs leverage both of these technologies to show users world-locked virtual objects and environments. Geometric errors introduced by inaccurate head tracking and distortions from HMD optics can lead to perceived instability in the rendered content, resulting in reduced immersion and, potentially, visually-induced motion sickness. Perceptual artifacts from inaccurate head tracking and optical distortion are most visible when users move their head and eyes as dynamic errors that vary with user movement result in apparent motion–a phenomenon underscoring the requirement to study these artifacts with active observers. Paradoxically, the engineering requirements to eliminate visible artifacts from inaccurate tracking and near-eye optics are unknown because the vehicles that can support active observer psychophysics to study these problems are incapable of creating a distortion-free experience. Even if such a system existed, it would be difficult to carefully derive perceptual requirements to pass the Visual Turing Test as these problem spaces are highly dimensional and difficult to sample efficiently with traditional psychophysics. We address both of these problems, first by introducing a reference-grade HMD simulator, free of near-eye optics with highly accurate head and eye “tracking.” Second, we introduce high-dimensional psychophysics with AEPsych, a modeling framework which facilitates highly-efficient psychophysics for multidimensional problems. We use these systems to study perceptual requirements for perspective-correct rendering with moving observers and eye-tracking requirements for gaze-contingent optical distortion correction for near-eye optics. We conclude with a final study on oculomotor and perceptual adaptation to visual-vestibular conflict, and explore how changes in action and behavior might be leveraged to characterize image artifacts in lieu of psychophysical measurements.

Symposium 7 - Spanning the space of science: from cones to colour applications. A symposium in honour of Sophie Wuerger

Space, Time, and Color in Human Vision

Andrew Watson[1]
[1]Apple (US)
At the dawn of the new Millennium, Sophie Wuerger arrived in California, and there was light. In that light she gently coaxed Albert Ahumada and myself out of our gray world, and into a new universe of color. Initially blinded by the spectral complexity, we eventually proposed some simple ideas to describe visual processing of space and color [1]. Those ideas grew, in both Sophie's work and our own, to include time as well. In this talk I will show how these ideas have over time yielded a general framework for understanding visual sensitivity to variations in light over space, time, color and eccentricity.
[1] Wuerger, S., Watson, A. B., & Ahumada, A. J., Jr. (2002). Toward a standard observer for spatio-chromatic detection. Proceedings of the SPIE, 4662(19), 159-172.

Contrast vision at and above threshold

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In honouring the remarkable contributions of Sophie Wuerger to the field of vision science, my talk will present her contributions in one of the research areas she had been passionate about—the human contrast vision. I will summarise the findings from a series of works focused on understanding contrast vision across different luminance levels, particularly at and above the perceptual threshold. The high-dynamic range contrast sensitivity dataset collection work that started in 2019, showed key trends in human contrast vision change with luminance levels for both achromatic and chromatic stimuli. Building on these insights, we proposed several computational models of human contrast vision which were shown to predict not only our own datasets but various other datasets available in the literature as well. We also explored spatio-chromatic contrast sensitivity across two different age groups and identified significant interactions between age, light levels and spatial frequency. The work on suprathreshold contrast matching shows how contrast matching between two very different light levels does not follow the contrast constancy principle for all three cardinal colour directions and that the magnitude of contrast required to match appearance is highly dependent on the difference of matching light levels. This phenomenon

was observed to be consistent across younger and older observers, suggesting a remarkable preservation of contrast perception across different luminance levels with ageing.
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A new spectra database of human skin colour

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Skin colour is one of the most commonly observed colours in our daily life. There has been a recent resurgence in interest in skin colour appearance, driven by new technologies and multi-disciplinary application areas where accurate measurement and understanding of the factors that influence perception are critical. The inherent complexity of skin – characterised by non-flat, uneven surface and complex multi-layered composition – presents substantial challenges for consistent colour measurement, resulting in variability across different instruments and settings. None of the existing skin colour databases can adequately represent the wide diversity of human skin across ethnicities, genders, ages and body locations. Over the past decade, efforts have been focused on creating a comprehensive skin spectral database. This project, initially led by University of Liverpool and subsequently by University of Leeds, has involved collaboration with nine global organizations. Eleven separate data sets of spectrophotometric measurements of skin reflectance were collected from over 15,000 skin patches across the UK, Spain, China, Thailand, Iraq, Japan, Saudi Arabia, Tanzania and Pakistan, all following the same measurement protocol. Our analysis of this dataset reveals overlaps in skin colour distributions within the CIELAB colour space under D65 lighting across various ethnic groups. Notably, the spectral reflectance patterns also exhibit a high degree of similarity. For instance, the skin colours of Caucasian and Chinese individuals not only overlap significantly but also exhibit very similar spectral reflectance shapes. The findings provide evidence that distinguishing ethnic groups based solely on their skin colour lacks scientific validity. Additionally, gender and age influence skin lightness; females generally have lighter skin than males, and younger participants displayed slightly lighter skin than older ones. This new database, which will soon be made publicly available, promises to support a wide range of research fields and applications.

Colour in motion: global motion filters, grouping-by-colour and attentional selection

Jasna Martinovic[1]
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I began my scientific career as Sophie Wuerger's research assistant, studying the chromatic sensitivity of global motion mechanisms. We made several observations that could not be explained by simple summation models: (1) performance in a global motion coherence detection task was considerably worse when local motion signals had to be combined across two colours as opposed to all being defined by a single colour, implying an obligatory grouping that preceded and interfered with motion integration; (2) in a two-colour random dot kinematogram (RDK) segregated into 50% noise and 50% coherent motion signals, cueing to the signal colour generally resulted in performance benefits, but these differed substantially between hues. The likely culprits in driving these effects – grouping-by-colour and attentional selection – required a dedicated research programme to disentangle their effects. I returned to Sophie's lab after my PhD to continue investigating colour-based attention, but our efforts came against the obstacle that potential drivers of selection efficiency were manyfold – cone-opponent, colour-opponent and categorical processing could all exert an influence. Years later, we joined forces with selective attention researchers and captured increases of steady-state visual evoked potentials elicited by individual colours in flickering RDKs containing two target and two distractor colours, in two different colour contexts. We built a model that showed that their main determinants of were (1) proximity between the two targets and (2) the particular configuration of colours within which these targets were presented. This model is highly similar and compatible with the recent proposition of good-enough attentional guidance in visual search, which posits a flexible and context-dependent allocation of resources. Further experimental testing of predictions derived from our model has the potential to yield highly useful information on mechanisms of colour-based attention.
Acknowledgements: Wellcome Trust.

Principled approaches towards a better understanding of multisensory perception

Georg Meyer[1]
[1]University of Liverpool (UK)
Sophie was foremost a colour vision scientist. I was lucky to work on a number of 'extracurricular' projects with her over more than twenty years. One of them was 'multisensory perception'. She was very much influenced by her first degree, which, while formally in psychology, in reality was in mathematics and philosophy, and her PhD at NYU, where she learnt to combine mathematical rigour with experimental psychology to great effect. Her approach was – like most things she did – principled and non-negotiable: science needs (mathematical) models to provide predictions, which can be rigorously tested against experimental data. An example is to test which distance metric (Euclidean vs City Block) best models human colour difference judgements (Wuerger, Maloney and Krauskopf, 1995) - it's not Euclidean. This principled approach also guided her work on multisensory perception with me and our many collaborators. I will use this talk to show how the principled use of theoretical models, many of which derived from colour vision research, can be used to great effect to test hypotheses about the integration of signals across modalities.

Talk Session 10 - Spatial Vision

The CRIP effect: patterns in central vision interfere with perception of patterns in the periphery

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We introduce a novel phenomenon, in which elements in the central region impair perception in the periphery (Central Region Interference with Periphery: CRIP). In a series of four experiments, we showed participants a squared grid containing small lines (vertical or diagonal) or crosses (X). Between the central and peripheral regions there was a gap (blank space with no grid and no lines). Participants reported: 1) what they saw in the periphery (Xs, lines or nothing, subjective report) and 2) the orientation of the lines in the periphery with a 2AFC task (objective report). We varied the size and position of the gap (within experiments), and the orientation of the lines in the centre (between experiments: Xs, vertical lines, diagonal lines). For subjective reports, observers could see the presence of elements in the periphery. For the objective report, the central pattern caused interference and hindered identification of the orientation of the peripheral elements, even though the two surfaces were clearly demarcated by a visible gap. The smaller the gap (central and peripheral elements were closer) the larger the impairment, independently of the eccentricity of the peripheral elements. The impairment was only present when the central elements were Xs or diagonal lines, suggesting that orientation plays a role in the CRIP effect. When the central elements were diagonal, performance was worse when central and peripheral lines had the same orientation. We conclude that people do not always rely on uniformity when perceiving elements in the periphery, and that iso-orientation may cause greater interference.
Acknowledgements: Funded in part by PRIN DM104 awarded to Bertamini.

From Curvature to Contour: Hierarchical Representations of Contour Shapes in Terms of Constant Curvature Segments

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[1]Loyola University Chicago (US), [2]Gonzaga University (US), [3]York University (CA), [4]Ecole Normale Supérieure (FR)
Introduction: We can discriminate a stunning variety of shapes. How does the visual system encode these different shapes? We investigated the hypothesis that the visual system forms hierarchically structured representations of contour shapes, based on primitives that represent segments of constant curvature (CC). This hypothesis implies that (i) in representing a contour, encoding of CC segments is obligatory; (ii) variation in CC segments will induce perceptible differences between contours; and (iii) CC segments can be organized perceptually into higher-order parts. Experiments: In Experiment 1, we displayed contours made from two curvatures and two colors. The transition point for color was near to, but offset from, the transition point for curvature. We then presented the contour again, sometimes shifting the color transition point. When asked whether the coloring was different, participants were much less sensitive to shifts that aligned the color transition with the task-irrelevant curvature transition than to equivalent shifts that increased misalignment. In Experiment 2, we compared participants' ability to discriminate between a contour fragment made of multiple curvatures and one made of one curvature. Sensitivity was considerably higher when multi-curvature contours were predicted to be represented with multiple CC segments than with a single CC segment. In Experiment 3, we tested a hypothesis that CC segments with the same curvature polarity are represented as higher-order "parts" of a contour. Following Palmer (1977), we tested participants' ability to say whether a contour fragment was part of a shape. Participants were significantly faster when the fragment was from a polarity-matched contour region. Performance using polarity-matched fragments was comparable to performance using segments between curvature minima. Conclusion: These experiments suggest that CC segments are obligatorily encoded in contour representation (Exp.1), that contour discrimination depends on encoded CC segments (Exp.2), and that CC segments organize together into higher-order units (Exp.3).
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Individuation and Pooling of information over different temporal scales

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Effective interaction with our environment requires us to focus on individual events as well as maintain an overall perception of our environment. For instance, individuating a single item presented within a sequence involves segregating its signal from the other items in the sequence. In contrast, capturing the global aspect of the sequence, such as its average orientation, requires pooling information across time. Understanding the relations between these two processes—individuation and pooling—and how they unfold over time has important implications for theories of visual perception, particularly regarding temporal crowding and averaging across time. Typically, pooling and individuation are studied separately. Here, we used the same stimuli and orientation-estimation procedure to examine both processes and particularly how they vary across different time scales. In five experiments, participants viewed a sequence of three oriented items, and either reproduced the orientation of the second item in the sequence (individuation) or reported the average orientation of all three items (pooling). The inter-item intervals (SOAs) were either of short scale (40-120ms) or long scale (150-475ms). Mixture-modeling analyses of the error distribution revealed distinct patterns of results for the different tasks and time scales. At the long temporal scale, the SOA affected encoding precision in both individuation and pooling tasks, albeit in different ways. Distinct SOA effects for the two tasks also emerged at the short temporal scale. Specifically, while the SOA affected the guessing rate in the individuation task without affecting precision, it affected precision in the pooling task without affecting the guessing rate. Furthermore, the short-scale SOAs affected the items' relative weight in a similar manner with both tasks, but distinct effects emerged with long-scale SOAs. These findings suggest that temporal individuation and pooling engage different processes, and each of these processes further reflects different mechanisms when considered over short versus long temporal scales.

Crowding considered as adaptive spatial integration

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Crowding is the inability to recognize an object in clutter, usually considered a fundamental low-level bottleneck to object recognition. We advance and test an alternative idea, that crowding, like predictive phenomena such as serial dependence, results from optimizing strategies that exploit redundancies in natural scenes. This theory leads to several testable predictions: crowding should be greatest for unreliable (non-salient) targets and reliable flankers; crowding-induced biases should be maximal when target and flankers are not too dissimilar (in orientation, colour etc); crowding can be associated with higher precision; effects should be maximal when the orientation

of the target is near that of the average of the flankers, rather than to that of individual flankers. We measured orientation and colour discrimination for targets flanked by stimuli of variable orientation or colour. The results of both sets of experiments supported all the predictions, and were well simulated with ideal-observer models designed to maximize efficiency. We conclude that although crowding is highly detrimental to object recognition, it may be better understood not as a processing bottleneck, but as a consequence of efficient exploitation of the spatial redundancies of the natural world.

Revealing Developmental and Cross-Species Asymmetries in Visual Performance

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Visual performance varies drastically not only across eccentricity but also around the polar angle. In human adults, it is better at the horizontal than the vertical meridian (Horizontal-Vertical Anisotropy, HVA) and at the lower than the upper vertical meridian (Vertical Meridian Asymmetry, VMA) in a variety of tasks (e.g., contrast sensitivity, spatial resolution, acuity). These asymmetries are pronounced, ubiquitous and resilient, and they are not ameliorated by covert spatial attention, pre-saccadic attention, or temporal attention. Here we investigated how these two asymmetries vary with age and whether they vary between human and non-human primates. We tested children, adolescents, and human adults in an orientation discrimination task, in which performance is contingent on contrast sensitivity. A target (Gabor) appeared at one of four locations: left- or right- horizontal meridian, upper- or lower- vertical meridian. We verified that participants maintained fixation throughout the trial. The typical Horizontal-Vertical Anisotropy emerged for all observers. The Vertical Meridian Asymmetry was absent in children, emerged in late adolescence, and was present in adults. We also tested human and non-human adult primates in a motion direction discrimination task. Stimulus presentation was contingent upon eye fixation, and we verified all participants maintained fixation throughout the trial. For both groups, there was a slight Horizontal-Vertical Anisotropy and a pronounced Vertical Meridian Asymmetry, but in the opposite direction: Human performance was better along the lower- than the upper-vertical meridian (like in other tasks) but macaques' performance was better along the upper- than the lower- vertical meridian. We discuss how several factors corresponding to different polar angle locations —such as the distribution of cones and midget retinal ganglion cells, the size of the cortical surface (V1), statistics of the environment, peri-personal space, and tool use—along with bipedal vs quadrupedal locomotion, may help explain these novel developmental and cross-species findings.

Expectations modulate the allocation of attention to familiar but not unfamiliar objects

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Irrelevant objects often interfere with target processing. Previous studies have shown that interference is reduced when the distractors are expected, compared to when they are unexpected. This effect of flanker expectation has been attributed to a narrowing of the attentional focus prior to stimulus presentation. Here we tested the robustness of this attentional modulation across eight experiments. In the first four experiments, participants were asked to identify pairs of numeric targets that were presented either with or without flanking letters. The probability, and thus participants' expectations, of flanker presence was systematically manipulated. Across these experiments, we varied stimulus duration, target-distractor separation, target position, the number of distractors, and whether distractors were familiar or not. In all cases, we found a robust effect of expectation, wherein identification accuracy was higher when flankers were expected than when they were unexpected. In experiment 5, however, we tested unfamiliar letter-like targets and did not observe this effect of expectation. Experiments 6 and 7 further confirmed this lack of an effect for other unfamiliar targets while we manipulated expectations of flanker presence using different cueing paradigms. Finally, in experiment 8, we directly manipulated target familiarity within the paradigm used in experiments 1-4 and found an effect of expectation only for familiar targets. Taken together, expectations of flanker presence modulate the allocation of attention under a wide range of conditions, but not when targets are unfamiliar or when they require coarse discrimination rather than recognition. We argue that objects that cannot be recognised effortlessly draw on more attentional resources than familiar objects, and hence require attention to be allocated to the targets irrespective of context, leaving little room for modulating its spatial allocation.

Talk Session 11 - Virtual Reality

Memory limits on active visual search for coloured targets in virtual outdoor environments

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Natural outdoor environments contain complex distributions of surface colours, which can provide a challenge to using colour to guide exploration. How colour perception and memory limit active visual search in these environments is not well understood, not least because of the constraints of traditional laboratory experimentation. The aim here was to measure how memory affects active visual search by colour in two exemplary outdoor environments, both presented in immersive virtual reality. Participants wore a head-mounted display (Meta Quest 3, Reality Labs, 2023) while exploring simulations (Unity Game Engine v.2022.3.4f1, Unity Technologies) of a dense forest and a colourful city scene, modelled on real-world hyperspectral images. In each trial, participants viewed a coloured swatch, an enlargement of a randomly selected target point in the scene, and had to identify that target using a virtual laser pointer with precise position control. In the non-memory condition, eleven participants could refer back to the swatch while searching; in the memory condition, another ten participants viewed the swatch continuously for 4 seconds before searching without it. Each participant completed 100 trials with each scene. Participants were aged 18–53 years, with normal or corrected-to-normal visual acuity and normal colour vision. Performance was quantified by spatial distance errors and colour difference errors in an approximately uniform colour space. Memory had little effect on distance errors but a significantly larger impact on colour errors, and this was particularly evident in the forest scene with its smaller colour gamut. Although lightness errors dominated overall colour discrepancies, increases in saturation

errors occurred with low saturation targets in the memory condition. In summary, memory search may impair surface colour matching outdoors with effects varying with target and scene properties, especially colour gamut size. Understanding why requires experimental environments with a range of surface colour distributions.

Where is the door? Can people keep track of one environment while immersed in another?

Meaghan McManus[1], Franziska Seifert[1], Immo Schütz[1], Katja Fiehler[1]
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It is not uncommon when leaving virtual reality to find that we are facing a different direction than expected. In a series of 4 experiments, we investigated if people can keep track of an unseen environment while immersed in a different environment. In the first 3 experiments participants were asked to encode the location of target objects in one environment, either real or virtual, and then enter the second environment. While in the second environment they had to point to the now unseen target objects in the first environment. The virtual environment could be aligned or misaligned (pitched up or down) to the real world. In experiment 1 the misalignment was not detectable to the participants (±2.6°) while in experiments 2 and 3 the misalignment was obvious (±20°). In experiment 3 the instructions were also changed to prime egocentric (object-relative-to-observer) encoding. In all three experiments the pointing endpoints were based primarily on the locations of objects in the currently seen environment suggesting a strong reliance on allocentric (object-relative-to-environment) encoding. This could be due to participants either not updating egocentric information when they or the environment changed or participants not maintaining a representation of the unseen environment. To test this in a fourth experiment, participants walked to different locations in different virtual environments while simultaneously keeping track of the unseen real-world location of the door. When a virtual door was presented in the virtual environment the pointing errors were based on the currently seen environment with no change over time. When no virtual door, or other objects, were presented in the virtual environment, pointing endpoints were highly variable within and between participants. Overall, it appears that when in an immersive environment, people quickly forget about their position in the unseen environment and use the available visuo-spatial information to plan their actions.
Acknowledgements: This project was supported by the Collaborative Research Center SFB/TRR 135, project A4, under grant agreement no. 222641018, and 'The Adaptive Mind' funded by the Hessian Ministry for Higher Education, Research, Science and the Arts.

Relative walking speeds of neighboring pedestrians capture visual attention and influence room evacuation behavior

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We examined how the relative walking speeds of neighboring pedestrians influence visual attention, exit decisions, and exit times in an immersive virtual reality (VR) environment and validated this approach using a carefully matched real world condition. The participants' task was to exit the room along with two other pedestrians (experimentally manipulated avatars in VR and confederates in the real world) when cued, through one of two doors. For each trial, a variable pedestrian walked towards one door by traveling at one of three average speeds (1.0m/s, 1.5m/s, or 2.0m/s), and a constant pedestrian walked towards the other door at a speed of 1.5m/s, resulting in three relative walking speeds (-0.5 m/s, 0 m/s, and +0.5 m/s). Pedestrian exit door was counterbalanced, which resulted in six randomly presented trials in VR and six matched trials in the real world, and the VR/real world condition order was counterbalanced across participants. We analyzed fixation durations via pedestrian AOIs and found that faster moving pedestrians captured participants' visual attention. Similarly, exit choice results revealed that participants were more likely to follow faster pedestrians and less likely to follow slower pedestrians. The overall walking speeds of neighboring pedestrians also impacted exit times, as participants exited sooner when neighboring pedestrians walked faster. Effects were analogous for VR and real-world conditions, substantiating the use of VR in the context of room evacuation decision making. Overall, results suggest that visual motion cues can systematically bias visual attention and exit choices, and influence exit times in room evacuation scenarios.
Acknowledgements: This work was supported by funding through the Environmental Quality and Installations Basic Research Program of the U.S. Army's Engineering Research and Development Center (project #17-111).

Avatars with faces of real people: State of the art in experimental psychology

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Virtual reality (VR) paradigms are applied increasingly in experimental psychology to study human behaviour and cognition. These applications make use of avatars as human agents, with which participants must interact. However, the extent to which avatars visually represent real people is still captured poorly in VR experiments. We illustrate a method for creating avatars with the faces of real people for behavioural experiments and demonstrate their psychological characteristics. In a series of experiments, we examine the recognition of avatars of familiar people, the identity matching of unfamiliar avatars, and compare the similarity-space occupied by avatars and real photographs of the same faces. We then examine the photo-realism of avatars by determining the extent to which these can be confused with images of real faces. These studies demonstrate the current state of the art of avatars for psychology experiments.

Best practices of mobile eye tracking in outside urban environments

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Vision is one of the most important senses for spatial navigation. However, using eye-tracking to investigate spatial navigation in real-world environments results in many challenges. Upon receiving the Tom Troscianko Memorial Award in 2023, we took the opportunity to transfer a virtual reality (VR) study to the real world in Cyprus as a single-subject case study to develop best practices for mobile eye-

tracking in outside environments. The mobile eye-tracking study in the city of Limassol was conducted as close as possible to the original design in VR. First, the subject explored the city for 130 minutes, followed by pointing-to-building and pointing-to-north tasks. Eye-tracking, head-tracking, GPS data, and a continuous video of the subject were recorded. Additionally, validation and synchronization procedures were performed every 10 minutes. During the data analysis, we critically examine the accuracy of the devices and the effectiveness of the validation and synchronization procedures. The conditions during the data recording and the analysis results serve as the basis for the developed list of best practices. The best practices for mobile eye-tracking in real-world environments include:
- Experiment design adaptations (e.g., time management, weather considerations, selection criteria of the experimental area and task buildings) - Data quality and validation procedures (e.g., eye-tracking accuracy, head-tracking alignment to cardinal directions, recording durations, backup recording systems) - Synchronization of different data streams (eye-tracking, head-tracking, GPS, video) - Pointing tasks and cardinal directions - Transport of the subject - Interactions with people during the recording. Overall, the case study showcases the feasibility of mobile eye-tracking in real world outside environments while highlighting the best practices to ensure a successful transfer of the experiment design from the lab to the real world while maintaining data quality.

Comparing gaze behavior during free spatial exploration in virtual reality and the real world

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Eye tracking in real-world environments comes with many challenges. Therefore, visual behavior during spatial navigation is often investigated in virtual reality instead. Receiving the Tom Troscianko Memorial Award 2023 allowed us to challenge this approach and transfer a virtual reality study to the real world city Limassol in Cyprus. Matching the original experiment design in virtual reality, the participant first explored the city for 130 minutes with a walking speed of 4.5 to 6 km/h, followed by pointing-to-building and pointing-to-north tasks. Throughout the experiment, eye-tracking, head-tracking, and GPS data were recorded. To label the eye-tracking data, we apply an automatic object recognition pipeline to the world camera images using the 'SAM' (segment-anything) and Segformer (cityscapes) computer vision models. Ambiguous labels are solved through a four-stage decision-making process. The performance of this pipeline was compared to that of manually labeled data, resulting in a weighted mean accuracy of 91.3%. When comparing eye movements and gaze distribution over object categories, we find many similarities between the real world and virtual reality, however, more gazes are located on buildings in the real world. As a last step, we apply a graph-theoretical analysis to the eye-tracking data in close analogy to our previous work. First, we identify the viewed buildings and create a gaze-graph. Then, the gaze-graph is analyzed with graph-theoretical measures and ultimately combined with the results of the pointing tasks (mean pointing-to-north error: ~11°, mean pointing-to-building error: ~29°). Finally, we compare the graph-theoretical findings in the real world with our findings in virtual reality, further investigating the similarities and differences in viewing behavior. Overall, our work highlights the feasibility of mobile eye-tracking research in outdoor environments while also providing a new perspective on similarities and differences in visual behavior during spatial exploration in virtual reality and the real world.

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Visual Memory of Body Postures is Biased by Distinct Sources of Knowledge

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We human beings have built rich knowledge of socially relevant objects like bodies. Prior knowledge can lead to biases towards the more likely interpretation in perception and memory. In a previous study, we revealed how visual memory of body postures is biased by two types of body-related knowledge: 1) Lifted limbs were remembered as lower, reflecting an embedded understanding of gravity; 2) Extreme postures, such as bending the arm far behind the back, were remembered as the more plausible postures, reflecting the knowledge of biomechanical constraints. In a new series of experiments using full-range postures combined with a motion capture dataset, we demonstrate that the biomechanical constraint bias happens for postures that are impossible in real life. By contrast, no such bias was found for a mechanical control object with a body-like structure. These results suggest an interplay between domain-general and domain-specific knowledge, raising the question of whether these two sources of knowledge rely on the same mechanism. To answer this question, we manipulated sensory uncertainty by varying the memory delay or stimulus blur level. Results showed that while the gravity bias appeared quickly (within 250 ms) at the lowest blur level and remained stable, the biomechanical constraint bias took time to emerge and increased over time. This dissociation indicates that general knowledge is activated quickly and automatically while specific knowledge requires controlled processing. Taken together, these studies illustrate how our visual memory of body postures is shaped by distinct mechanisms based on multiple sources of knowledge.
Acknowledgements: This project has received funding from the China Scholarship Council (CSC), European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie (grant agreement No. 101033489), and European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 725970).

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Investigation of the effect of subjective visual awareness on audio-visual interactions under continuous flash suppression

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Concurrent audio-visual stimulation is typically processed more efficiently than its unimodal stimulus components, resulting in improved target detection and faster reaction times. However, these behavioural benefits in multisensory interactions can be diminished when visual information is weak and does not enter subjective awareness. This raises the possibility that audio-visual processes may differ between conditions under which visual information is either seen or not. This study investigated the neural correlates of audio-visual processing under continuous flash suppression (CFS), a visual masking paradigm used to achieve conditions under which participants were only sometimes aware of the visual targets presented. Participants' EEG, manual reaction time, detection accuracy, and subjective awareness of visual targets were recorded as they responded to visual, auditory, and audio-visual stimuli. Analysis of event-related potentials (ERP) revealed no evidence for multisensory integration in early sensory cortices for audio-visual targets. Instead, the audio-visual ERP was characterised by a combination of independent activation in each sensory modality. Provisional analysis of EEG signals when participants were unaware of the visual stimulus suggest that ERPs elicited by auditory only stimuli, and auditory stimuli paired with an unseen visual target did not differ significantly, mirroring the behavioural data obtained under the two conditions. Further, signal detection analysis of behavioural responses in aware conditions showed that participants' response criterion was lower when the visual target was paired with an auditory target, suggesting they were more likely to report visual awareness when an auditory target was present. Similarly, while reaction times were faster in multisensory trials when awareness of visual target was reported, this difference did not exceed what could be expected from probability summation. Combined evidence from EEG and behavioural measures supports the race model as a plausible explanation for the speed-up of reaction times in audio-visual trials when the visual target is masked under CFS.
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Similar area of direct looking and direct pointing

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Gazing and pointing can have overlapping functions in social interaction. The perception of both social cues is remarkable precise. Nevertheless, the perception of direct gaze is characterized by an area of direct gaze rather than one single gaze direction. In fact, observers accept a range of gaze directions as direct. Here we investigate if there is an analogous area of direct pointing. Three experiments examine an area of direct pointing (about 5 – 9°) and compare it to the area of direct gaze. We find this area to be similar, but not equal, in shape and size. Furthermore, we examine the influence of different pointing gestures on the area of direct pointing. Results indicate a shift of the area of direct pointing dependent on the shown hand and forearm (left or right). The results are discussed with respect to common underlying mechanisms of the perception of direct gaze and direct pointing.

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Signal detection under spatial uncertainty

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Signal detection theory is often used to model psychophysical tasks in which an observer is tasked with discriminating a target from a distracter. It relies on the assumption that both the target and distracter lead to distributions of internal states, and the separation between these distributions determines sensitivity. This separation will vary systematically with where the signal falls on the retina, making it necessary to hold constant the signal location when measuring sensitivity under SDT. However, in many circumstances the observer does not already know where exactly the signal will be. Under conditions where the location of the signal is not known in advance, SDT is likely to overestimate the actual rate of detection because spatial attention can be assumed to be directed to the signal's expected location; the enhancement of perceptual sensitivity associated with spatial attention is well established. We present a method for estimating sensitivity for multiple locations simultaneously, representing the range of possible stimulus locations and assuming an increase in internal noise with eccentricity. This measure can provide more accurate parameter estimates for sensitivity and decision bias in circumstances such as visual search where the location of the target is not known in advance. We simulate an experiment in which an observer is repeatedly asked to detect a spatially-uncertain target. If they detect the target they are asked to respond with a mouse click on its location, otherwise, they respond Target Absent. We present analytic and machine learning methods for recovering the underlying "visibility map" from these data, and discuss some limitations and assumptions required to psychophysically collect the data required from human observers.

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Looking with or without seeing in an individual with macular degeneration impairing central vision

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Macular degeneration (MD) impairs central vision. An 86-year-old woman with age-related MD no longer reads, but can manage most sorts of housework. She was asked to find a uniquely oriented bar among many identically shaped bars in each of many images, each could be of type A-simple, B-simple, A, or B. In A-simple images, all bars are oriented 45 degrees clockwise or anti-clockwise from vertical; the target is uniquely oriented. Modifying A-simple images gives A images, when to each original bar is added an intersecting horizontal or vertical bar to make an 'X'. All the 'X's are identical to, although rotated from, each other, confusing normal observers and prolonging their response times (RTs) to report the target (Zhaoping and Guyader 2007). In this confusion, gaze position during search often reaches, but then abandons, the target to continue searching elsewhere. Modifying A images gives B images, when the target bar's orientation tilts just 20 degrees from the intersecting horizontal/vertical bar, making the resulting 'X' distinctly thinner, eliminating the confusion.

Removing all the horizontal/vertical bars from B images gives B-simple images. Unlike age-matched control observers, the MD observer performed similarly for A and B images. Her accuracy (probability of reporting by touching at/near the target within 60 seconds) for A and B was ~30%, much higher than chance (4%), but much lower than her 100% accuracy for A-simple and B-simple. She complained that the search items were too small. When the search items were enlarged (but were then fewer in number), the complaints disappeared and her accuracy for B improved; however, for A her RT more than doubled and her accuracy dropped. Her behavior supports the Central-Peripheral Dichotomy theory (Zhaoping 2019) that peripheral and central vision are mainly for looking and seeing, respectively. Looking shifts gaze and attention, whereas seeing recognizes objects.
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Sense of agency at a gaze-contingent display with jittery temporal delay

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In network-based human-computer interaction, inconsistent temporal delays between an action and its feedback can significantly affect users' perceived authorship; however, this research area remains underexplored. This study investigates the effects of such delays on the sense of agency (SoA) in eye-gaze-controlled interactions. Participants engaged in a visual search for Chinese characters on a display with dynamically adjusted resolution based on gaze direction: a high-resolution image placed at the gaze point and a low-resolution image in the periphery. We introduced jitter delays in display updates following eye movements, based on a truncated normal distribution ranging from μ to μ + 2 σ, with means (μ) varying from 0 to 400 ms and a constant standard deviation (σ) of 50 ms. A condition featuring playback of recorded eye movements assessed the perception of authorship by external agents. Findings show a decrease in reported authorship and controllability scores as μ increased, aligning with prior research on consistent delays. A significant reduction in perceived authorship occurred at a μ of 94 ms. While delays did not affect the number of fixations required for searches, they reduced search time efficiency and prolonged latency to fixation durations. An increased number of smaller saccades (< 1 deg) with increasing μ suggests a covert shift in attention to the spatial gap between eye movement and visual feedback induced by temporal delay. In sum, observed changes in eye movements highlight the delay's influence on attention distribution and visual search. Comparing jittery and consistent delays, our findings indicate that the minimum value (μ) within the delay distribution significantly impacts SoA and visual search efficiency. We posit that sporadic extended delays weaken SoA. Hence, future studies should broaden their scope to include a more extensive spectrum of delays and manipulate their frequencies to better understand their effects.
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The effects of serial dependence on the variability of perceptual estimates: A meta-analysis

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Recent research on serial dependence has revealed systematic biases in perceptual decisions towards prior stimuli. Theoretical and computational frameworks suggest that serial dependence arises from the optimal integration of stimulus history. Besides predicting the bias pattern, these frameworks bring forward a crucial, but untested, hypothesis: when current and prior stimuli resemble each other, serial dependence enhances perceptual decision-making by decreasing response variability. To test this hypothesis, we conducted a meta-analysis of 20 datasets. Contrary to the predictions of models using optimal integration, our results do not support performance improvements in serial dependence. Instead, we found that previous stimuli can deteriorate perceptual performance. These findings challenge existing models and call for a reassessment of serial dependence, suggesting new avenues for investigation.
Acknowledgements: This research was supported by funding from the Swiss National Science Foundation (grant no. PZ00P1_179988 and PZ00P1_179988/2 to DP). The funders had no role in study design, data collection, and analysis. The authors would like to thank the research groups of the original studies for sharing their datasets, and Joao Barbosa, Heike Stein, and the group of Prof. Michael Herzog for constructive comments and helpful discussion.

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The Role of Neural Oscillations and Aperiodic EEG Signals in Contrast Detection

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Perception of a constant weak visual stimulus will vary from trial to trial, demonstrating that visual perception depends not only on the sensory input but also on the current state of the brain. Electrophysiological work has attempted to explain this trial-by-trial behavioural variation by linking perception with spontaneous brain states, such as neural oscillations within early sensory cortices at the time of visual stimulation. Several early studies demonstrated that people are more likely to report the presence of a faint visual stimulus at certain moments, or phases, within oscillations in the 8-14 Hz 'alpha' frequency band. Such studies used a simple detection paradigm, which cannot rule out that neural oscillations might reflect changes to an observers' perceptual or decision threshold rather than their perceptual sensitivity to the stimulus. To address this, we tested eight participants over multiple sessions of an objective two-alternative location discrimination task that was not reliant on subjective reports of stimulus presence. We used a signal detection theory approach to model the influence of EEG alpha oscillation phase on the psychometric function relating stimulus contrast to performance. Our results show that alpha-band phase does not influence perceptual sensitivity, in line with a growing number of null reports. Alternatively, we

found that detection was predicted by changes in the non-oscillatory 1/f spectral component of occipital EEG prior to stimulus onset. This suggests that perception of near-threshold stimuli is influenced by spontaneous changes in broadband neural activity, which relate to the balance of excitation and inhibition within neural networks. Our data are consistent with an account that neural oscillation phase could predominately reflect the setting of perceptual criterions, as has previously been shown for alpha power. In contrast, sensitivity may be more strongly influenced by broadband spectral fluctuations.

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Navigational Affordance is related to Occipital Place Area and MEG signals between 100 and 200ms

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The elements in a scene give visual cues as to the actions permitted in the environment, which obstacles to avoid and which paths to take, known as navigational affordances. We aimed to establish the contribution of the Occipital Place Area (OPA) to this essential human behaviour and also determine the time course of processing navigational affordance. To that end, we used an event-related design to present 50 images of scenes to 14 participants in both functional Magnetic Resonance Imaging (MRI) and magnetoencephalography (MEG). OPA was defined using a localiser - scenes vs faces - and the navigational affordance of each scene was determined by path drawings of a separate participant group. First, functional MRI data were extracted from OPA, then a mean representational dissimilarity matrix (RDM) was calculated for the 50 scene stimuli. Similarly, RDMs were calculated at each timepoint of the MEG responses. OPA functional MRI and MEG RDMs were then correlated with behaviorally defined navigational affordance RDMs. The distribution of correlations between OPA and navigational affordance RDMs was significantly greater than zero, consistent with previous work and suggesting some processing of navigation affordance in OPA. In MEG, the correlation between navigational affordance and MEG RDMs differed significantly from zero, with an early peak at around 100ms and later between 225ms and after stimulus offset. We then performed fMRI-MEG fusion and again found an initial peak between 100 and 200ms. The MEG correlations with navigational affordance and MRI, which occur around 200ms, are consistent with the interpretation that MEG can track extrastriate processing of navigational affordance, which may be taking place in OPA. Future work will evaluate the correlations between MEG and other visual areas of the brain to establish the specificity of navigational affordance processing that is captured by fMRI-MEG fusion analysis.
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Measuring the speed of action recognition

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Many high-level stimuli are processed very quickly by the human visual system. While we have some knowledge regarding the time-course of visual processing of objects and faces, much less is known about the time-course of action processing. This question is important because an “action recognition” system would hypothetically need to process and integrate information from various domain-specific systems, including those involved in object, person, and scene recognition, and as such might be expected to take substantially longer than recognition of any one of those scene elements on its own. Our participants (N=96) completed a same-different task on pairs of action images that were presented briefly followed by a mask. In "same" trials, the two images could be: the identical image shown twice; an action image followed by its mirror-reversal; or two instances of the same basic action (e.g. biking). In "different" trials, the two images could be from two different actions within the same superordinate (e.g. transport: biking and running), or from two different superordinates (e.g. biking and cooking). By varying the image presentation time, we aim to uncover how long it takes for actions to be encoded at the highest perceptual level. These findings might place constraints on our understanding of how multiple scene cues are integrated in order to classify actions by their category and, more broadly, how visual action recognition is structured in the mind.
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Examination of the effect of aspect ratios on the letter-row tilt illusion in non-staircase stimuli

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The letter-row tilt illusion is an illusion that the row is perceived to be tilted, when a set of letters is repeated in a physically horizontal or vertical row. We quantitatively examined the effect of aspect ratios of letters on the letter-row tilt illusion that did not correspond to the staircase hypothesis of horizontal line segments. The method of adjust was used. There were 5 aspect ratios of letters: 1.0:1.0, 1.5:1.0, 1.5:1.5, 2.0:1.0, and 2.0:2.0 H:V ratios. The results showed that the aspect ratios significantly affected the amount of the illusion that did not correspond to the staircase hypothesis of horizontal line segments. The results showed that the amounts of illusion in letter-rows that did not correspond to the staircase hypothesis had different tendency in the aspect ratios from those corresponded to the staircase hypothesis shown in Araragi and Ito (2023). The present study suggested that the mechanism underlying the letter-row tilt illusion differed in letter-rows that corresponded and did not correspond to the staircase hypothesis.

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Effects of object-based predictions and prediction robustness on subjective visual perception

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Throughout our daily experiences, we learn regularities about contextual associations between objects and scenes which are used to form predictions about the likely features of the environment and facilitate perception of noisy visual input. Our recent studies showed that blurred objects that can be predicted based on contextual information appear subjectively sharper than the same objects that cannot. However, current predictive processing theories suggest that these effects may depend on the robustness of predictions. Additionally, there is neuroimaging evidence suggesting that object-based predictions can reciprocally influence the processing of scene context. Our study aimed to address these two hypotheses at the perceptual level using a blur matching task in two Experiments. In Experiment 1, participants (n = 65) saw two images depicting two versions of the same scene containing a blurred object and had to adjust the blur level of the right object to match the blur level of the left one. We manipulated the robustness of context-based predictions about the object in scene pairs by varying the phase coherence of their contextual information (allowing to form weak to very robust predictions). Blur-matching errors suggested that robustly-predicted objects were subjectively perceived as sharper than objectively similar objects benefiting from weaker predictions and this effect increased with the relative robustness of predictions. In Experiment 2, participants (n = 30) had to adjust the blur level of the right context to match the left one. This time, we manipulated object information allowing to form prediction about the context: one scene contained an intact object (predictable context), while the other had a phase-scrambled object (unpredictable context). Results showed that at objectively equal blur levels participants perceived predictable contexts as sharper than unpredictable ones, indicating that object-based predictions sharpen the perception of noisy contextual information. These findings further precise how predictions shape subjective perception.
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The impact of sensory cues on multiple object tracking performance: behavioural and neural correlates

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Behavioural studies have demonstrated that additional sensory cues presented on target objects can elicit an enhanced tracking performance in a multiple object tracking paradigm compared to when no cues are presented. The aim of this study was to investigate the neural mechanisms of target enhancement driven by sensory cues, examining the early stages of sensory processing in the time frame of 100 ms after stimulus onset (N1) as well as subsequent post-perceptual processing stages ≥ 200 (P2). Twenty- one participants aged 18- 54 years tracked five target objects amongst five indistinguishable distractor objects. During tracking, target objects collided occasionally with the inner boundary of a central circle and elicited additional uni- sensory (auditory, visual), multi-sensory (audio-visual), or no rebound cues. Using a mark-all procedure, participants indicated the objects that they believed to be the original targets. Behaviourally, it was found that participants tracked a higher amount of target objects when the visual and auditory cues were present compared to absent. During the early time range of the N1, a stronger negative neural signal recorded at posterior clusters in response to the audio-visual cues was associated with improved tracking performance when audio-visual rebound cues were presented. In the later processing time windows, such as the P2, a more pronounced positivity to ERPs recorded to the audio-visual and the visual condition was observed compared to the baseline (no-cue condition). Implications of these findings suggest that sensory cues enhance target detection and that audio-visual sensory cues impact tracking functions at an early neural processing time window (time range of the N1), indicating a possible interaction between top-down and bottom-up processing mechanisms during multiple object tracking.

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Electrocardiogram (ECG) interpretation improves following priming with normal ECGs: An eye-tracking study among medical students

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Inaccurate interpretation of electrocardiograms (ECGs) is a life-threatening issue, with estimates of abnormal ECGs misinterpreted by medical residents at 58%. ECGs display the electrical activity, and therefore health of function, of different areas of the heart through a series of line tracings. Interpretation, taught as early as the first year of medical school, requires visual search for abnormal patterns. Eye-tracking is therefore well placed to elucidate successful interpretation strategies. We carried out an eye-tracking study among medical students (n=34) investigating the impact of priming with normal ECGs on accuracy. Our hypothesis was that interpreters who knowingly viewed normal ECGs prior to interpreting ECGs with an unknown diagnosis would be more accurate. Each student was tasked with reading a range of ECGs after undergoing one of three different priming conditions. The first group (control) viewed normal chest radiographs. The second viewed normal ECGs, but without knowing that they were normal. The third group viewed the same set of normal ECGs, but were told they were normal. Students in the key priming group were faster and more accurate at diagnosing ECGs compared to other groups. Furthermore, we have shown that slower responses helps to predict inaccurate interpretation. We also provide a descriptive analyses of fixation patterns on critical areas of ECGs which will help us better understand successful visual search strategies. We hope to uncover actionable insights into successful ECG interpretation strategies to improve teaching of ECGs to healthcare professionals.

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A Fast Parafoveal Preview Effect for Face Gestalt but not Identity

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Prior to fixating objects, we typically select the saccade target using extra-foveal information. While it is clear that this extra-foveal preview influences processing of the saccadic target, the mechanisms underlying trans-saccadic perception remain a matter of debate. Here, we build on previous studies showing strong parafoveal preview effects for faces to investigate the temporal dynamics and features

of trans-saccadic face perception. Participants performed a gaze-contingent task in which an extrafoveal face stimulus (the preview) was replaced with a tilted face (the target) during a saccade directed to it. The task was to saccade toward the face and judge tilt direction as quick as possible. Previewed faces could be identical to the target (valid preview) or different (invalid preview). We ran two separate experiments with invalid previews consisting of either inverted faces or faces with a different identity. Additionally, on some trials we presented foveal or peripheral noise patches to test the potential influence on perisaccadic processing (based on theories of foveal recruitment to process extrafoveal stimuli and support trans-saccadic perception). The preview effect was quantified as the reaction time difference between valid and invalid previews. We computed a repeated measures ANOVA with preview (valid/invalid) and noise (no-noise, foveal, peripheral) as independent variables. We found a significant preview effect for face inversion but not for face identity, suggesting that parafoveal processing operates on the overall face gestalt. Noise had no significant main effect or interaction with preview validity, showing a lack of foveal recruitment in this task. We found a strong preview effect even though participants were asked to move their eyes toward the saccade target as soon as it appeared. Thus, our findings suggest that saccadic programming and processing of the extrafoveal saccade target, rather than prolonged preview or foveal recruitment, is sufficient for parafoveal preview effects in trans-saccadic perception.

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Spontaneous and voluntary blinks interact differentially with perceptual alternation in multistable perception

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Blinks have been proposed to correlate with changes in visual awareness. Recently, we demonstrated that voluntary blinks facilitated perceptual alternation during multistable perception, whereas spontaneous blinks did not (Sato & Kimura, ECVP 2023). The aim of this study was to investigate the reverse effects of perceptual alternation on spontaneous blinking. We used breaking continuous flash suppression as an experimental paradigm. The suppressor consisted of a color Mondrian pattern refreshed at 10 Hz, while the target was a Gabor patch (1.06 cpd, σ = 1°). The target luminance contrast was ramped up to its maximum (0.8) over 3.0 seconds. We analyzed the frequency of spontaneous blinks as a function of time after perceptual alternation. We compared this observed blink frequency with the random blink frequency (RBF), which was generated assuming that blinks occurred independently of perceptual alternation. The results revealed that spontaneous blinks occurred more frequently in the time range of 0.5 to 1.0 seconds after perceptual alternation compared to the RBF. This suggests that perceptual alternation induced spontaneous blinks. Moreover, this temporal association was also observed in trials where a spontaneous blink occurred before perceptual alternation. This finding reduces the likelihood of potential confounding factors, such as eye dryness and task-dependent disinhibition of blinking. Spontaneous blinking serves to lubricate the eyes, and the occurrence of blinks indicates weaker suppression of blinking during those trials. Furthermore, these findings were further supported by another experiment using bistable apparent motion stimuli. Specifically, spontaneous blinks occurred in a time-locked fashion after perceptual alternation, irrespective of whether a spontaneous blink occurred before perceptual alternation. Collectively, our study revealed reciprocal and differential relationships between different types of blinks and perceptual alternation: voluntary blinks facilitate perceptual alternation, and perceptual alternation induces spontaneous blinks.
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Proportional Rate Control: A Strategy for Both Patient and Impatient Drivers

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Recent work on optical variables and control strategies used in visually guided braking suggests that individuals use proportional rate (PR) control when controlling deceleration to avoid collision. They initiate braking at a certain PR value and control braking so as to maintain that value constant during the approach (Kadihasanoglu etal., 2021). The advantage of PR control over other control strategies such as constant tau-dot control (e.g. Yilmaz & Warren, 1995) is that it offers a range of PR values that could result in successful braking. Selecting a different PR value within this range will only affect the timing of the movement. In this work, we manipulated the timing of the movement by giving participants instructions with different time constraints and examined the resulting PR trajectories. Participants viewed computer-generated displays simulating an approach to an obstacle in the path of motion and used a brake to stop at the obstacle. Three groups were tested: fast (stop as fast as possible), slow (stop as slow as possible), and control (stop at the obstacle with no time constraint). The analysis revealed a significant main effect of the instruction type on the mean PR values during approach, $F(2, 57) = 19.046$, $p < 0.001$, $\eta^2 = 0.401$. Bonferroni adjusted pairwise comparisons indicated that the slow group had significantly smaller mean PR values (–7.11, SD=1.78) than the fast (–4.33, SD=1.09) and control (–5.36, SD=1.37) groups, whereas those for the fast and the control groups were not significantly different. The closer the mean PR value to zero, the later during the approach the braking is initiated. Consistent with the proportional rate control, the results provided evidence that participants used different PR values to accommodate different time constraints.
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Altered learning of stimulus distribution in individuals with autism

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Background: Autism Spectrum Disorder (ASD) is a highly prevalent neurodevelopmental condition of unknown etiology. There is growing interest in sensory processing in autism, and sensory symptoms have become a diagnostic criterion in ASD. Prevailing views explain this alteration due to the underuse of perceptual priors (pre-knowledge and expectations about upcoming stimuli). However, investigations of this hypothesis have yielded mixed results, suggesting that sensory symptoms rely on more nuanced alterations. Objective: Given these uncertainties, our study aims to investigate differences in learning stimulus probabilities between autistic and non-autistic individuals during a visual search task. Method: Two groups of participants, ASD (N = 34) and NT (N = 40), performed a visual search task for a singleton color in a briefly displayed array. To manipulate search color probabilities, in each trial, the target color and distractors were randomly selected and sampled from either a uniform (Experiment 1) or a Gaussian distribution (Experiment 2). Participants reported the orientation of the target. Results: For NT, accuracy was higher when the color target matched the mean of the color distributions. Accuracy decreases as target colors deviate from the mean, regardless of a uniform or Gaussian distribution. For ASD, however, accuracy was only higher at the mean target color in Gaussian distributions, not uniform. This finding suggests that individuals with ASD vary in their susceptibility to stimulus probability distributions. Conclusion: The results reveal that contrary to current views, autistic individuals can learn and form priors. Whereas non-autistic individuals demonstrated a bias towards the mean regardless of the distribution type, autistic individuals did not show this bias when the distribution was non-uniform. These findings emphasize the nuanced differences in how individuals with ASD form priors and expectations within the visual environment.

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Use of Volumetric Shading Information in Human and Artificial Object Recognition

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Object recognition is a crucial function of biological vision, but the mechanisms underpinning recognition are not well understood. One potential source of insight into the problem of object recognition comes from artificial neural networks (ANNs), which have attained humanlike performance levels in recognition tasks with natural images. However, evidence suggests that ANNs leverage different information than humans in the recognition task. Previous research found a texture-bias in ANNs' object recognition when shape and texture were decoupled. Humans, by contrast, were shape biased. When shape and texture are separated, information about the 3D structure of the object's shape is typically also lost. We studied ANNs' texture and shape biases with and without volumetric information to assess their sensitivity to shading and other 3D object cues. We generated a dataset of 240,000 images of 3-diminesional objects crosslinked with textures and rendered from various viewpoints. This dataset (ReTexture) contains images of models with both diagnostic and non-diagnostic textures, half of which are wrapped around the 3D model and half of which are laid over the shape through 2D masking. We used ReTexture to test humans and ANNs (ViT and ResNet-50) sensitivity to shape and texture when 3D information is preserved vs. removed. In the human experiment, we presented participants with images whose shape belonged to one category and whose texture belonged to a different category, comparing accuracy and response time when participants were asked to report the identity of the object's texture vs. its shape. We tested ANNs similarly but focused only on accuracy measures. We found that ANNs were significantly more shape-biased when volumetric cues were preserved in the image. Humans were highly shape-biased irrespective of 3D cues. These results suggest that ANNs are less sensitive to objects' bounding contours than humans but make use of local shading cues for object recognition.
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Gaze Behavior in Older Adults: A Comparative Study of Mild Cognitive Impairment in Naturalistic Tasks

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Major neurocognitive disorders, such as Alzheimer's disease (AD), present significant challenges to international healthcare systems (Wolf and Ueda, 2021). Early detection of cognitive impairments is crucial but remains logistically challenging. While conventional pen-and-paper tests demand extensive training to ensure standardized administration and accurate interpretation, notable technological advancements, like eye-tracking technology, are spearheading the development of procedures for early AD detection and facilitating the diagnostic process. Consequently, eye-tracking technology offers a promising, cost-effective, and non-invasive tool for early detection of neurocognitive disorders (Wolf et al., 2023). This study investigates eye movement behavior in older adults with mild cognitive impairment (MCI) compared to those aging normally. It utilizes an approach that integrates two decision-making paradigms (Wolf et al., 2018 & 2019) and a memory recall task to illustrate the pathophysiology of information search processes in MCI. Participants (N=50) underwent comprehensive cognitive assessments, including the Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA), supplemented by evaluations of nutritional status, sleep quality, and geriatric depression scales. The concerns regarding the social and economic implications of the increasing incidence of AD emphasize the necessity for reliable, non-invasive, and timely cognitive scoring methodologies. By integrating eye movement metrics with psychosocial assessments, the findings could advance the clinical diagnosis and monitoring of MCI and early AD, thus facilitating more effective interventions and personalized treatment strategies.

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Task demands, motor costs, and motivation interdependently determine haptic exploration duration

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Haptic exploration is the process by which humans gather sensory information through physical contact with objects. Previous research demonstrates that this process is inherently active and adaptive. Based on that notion, we hypothesized that humans optimize the duration of their haptic explorations, and that this optimization is shaped by an interplay of valuation and predictive processes, also taking costs such as motor effort into account. To study this, we assessed exploration duration and performance in a two-alternative forced-choice spatial frequency discrimination task under varying conditions of task demands, motivation, and motor effort. Task demands were manipulated by changing the discriminability of the virtual grating stimuli that were rendered by a force-feedback device. Motivation was manipulated by introducing different levels of monetary reward, and motor effort was manipulated by implementing forces counteracting the participants' movements while switching between stimuli. Participants were instructed to switch between stimuli after each single exploratory swiping movement and exploration duration was operationalized as the number of swiping movements across the stimuli per trial. We observed that higher task demands led to longer exploration durations, likely reflecting adaptation behavior that allows to attain a certain level of task performance. Moreover, higher reward led to extended explorations, which is consistent with the expected higher motivation to increase task performance. Further modulations by motor costs are discussed. Overall, we conclude that humans adapt the duration of their haptic exploration according to an interplay of the predicted task performance and the motivational value associated with correct task performance, trading it off with the motor costs associated with the exploration.
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No Evidence for Reduced Susceptibility to the Ebbinghaus Illusion in Children Across Different Methods

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Previous research has suggested that children exhibit a diminished susceptibility to the Ebbinghaus illusion. However, recent challenges to this notion have arisen, questioning the validity of this conclusion due to methodological choices and potential response biases. In this study, we utilised two commonly employed paradigms: the method of adjustment (MOA) and the 2-way alternative forced choice (2AFC). Building upon the recent debate, our hypothesis posited that young children would display lower susceptibility in the 2AFC condition, while no developmental differences would emerge in the MOA condition. Forty-two children between the ages of five and seven, along with thirty-nine young adults, participated in the experiment. They were tasked with either identifying the larger of two inner orange circles in the Ebbinghaus illusion or matching one of the inner orange circles to another. Results across both paradigms revealed no difference in susceptibility between young children and adults. The absence of reduced susceptibility in the 2AFC condition was attributed to the heightened cognitive abilities of the children tested, thereby diminishing their reliance on response biases. These collective findings underscore the influence of strategy employment and response biases on children's susceptibility to visual illusions, suggesting the necessity for further investigation into this area.

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Proactive distractor suppression in early visual cortex

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Avoiding distraction by salient yet irrelevant stimuli is critical when accomplishing daily tasks. One possible mechanism to accomplish this is by suppressing stimuli that may be distracting such that they no longer compete for attention. While the behavioral benefits of distractor suppression are well-established, its neural underpinnings are not yet fully understood. In an fMRI study, we examined whether and how sensory responses in early visual areas show signs of distractor suppression after incidental learning of spatial statistical regularities. Participants were exposed to an additional singleton task where, unbeknownst to them, one location more frequently contained a salient distractor. We then analyzed whether visual responses in terms of fMRI BOLD were modulated by this distractor predictability. Our findings indicate that implicit spatial priors shape sensory processing even at the earliest stages of cortical visual processing, evident in early visual cortex as a suppression of stimuli at locations which frequently contained the distracting information. Notably, while this suppression was spatially (receptive field) specific it did extend to nearby neutral locations, and occurred regardless of whether the distractor, a nontarget item or the target was presented at this location, suggesting that suppression arises before stimulus identification. Crucially, we observed similar spatially specific neural suppression even if search was only anticipated, but no stimuli were presented. Our results highlight proactive modulations in early visual cortex, where potential distractions are suppressed preemptively, before stimulus onset, based on learned expectations. In sum, our study underscores how the brain leverages implicitly learned prior knowledge to optimize sensory processing and attention allocation.

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Protracted development of gaze behaviour

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How does gaze behavior change with age? Adult gaze behavior towards complex scenes is largely driven by semantic content, as well as by visuo-spatial gaze biases, including the center and horizontal bias. Previous research suggests that these gaze preferences differ across various age groups. However, most studies involve small samples and compare only two or three age groups, with little focus on adolescence. In this study, we aimed to trace the developmental trajectories of semantic gaze biases and basic visuo-spatial biases across a broad age range. We collaborated with a science museum to build a fully automated eye-tracking exhibit, during which participants freely viewed 40 natural scenes—a short test of individual gaze behavior. Here, we present data from > 6,500 participants (41% female,

55% male, and 4% diverse), ranging from 4 to 72 years of age. We found a surprisingly protracted increase of text salience that stabilized at around age 21-26, while the salience of touched objects continuously declined until around age 17-20. Notably, while the proportion of dwell time on faces showed a steady decrease until age 15-16, the proportion of first fixation on faces continuously increased until age 17-18. In terms of visuo-spatial biases, we found a linear decrease in the central bias until young adulthood, alongside a parallel increase in the horizontal bias until ages 15-16, the latter matching developmental changes in visual sensitivity and cortices. Furthermore, while visual exploration linearly increased until age 23-24, gaze similarity between observers decreased from childhood until adolescence. Together, we demonstrate that fundamental aspects of adult gaze behaviour continuously develop over decades and become more canonical over time. I will discuss a possible connection between reported changes in high-level gaze behaviour and developmental changes in cortical selectivity along the ventral stream.
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Bifocal Alpha-band tACS Modulates Temporal Sampling in Visual Perception

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Perception requires a fine interplay between temporal integration and segregation mechanisms. Recent advancements have suggested that alpha oscillations (7-13 Hz) may play a role in shaping temporal integration windows in the visual modality, with faster alpha frequencies associated with finer temporal resolution. However, much of the literature relies on correlational evidence and psychophysiological estimates, and findings are not consistently replicated. Here, we investigated the causal role of alpha oscillations in defining temporal integration windows by means of transcranial alternating current stimulation (tACS) and electroencephalography (EEG). Over three consecutive sessions separated by washout periods, bilateral high-definition tACS was applied over parieto-occipital electrodes at either the individual alpha frequency (IAF), IAF+2, or IAF-2 Hz while participants (N=30) performed a two-flash fusion task. In the task, two flashes are presented in rapid succession separated by a varying interstimulus interval and participants have to report if they perceived either one or two stimuli. A mixed model analysis demonstrated that accuracy varied as a function of stimulation frequency, with stimulation at higher (lower) frequencies enhancing (reducing) task accuracy. This effect was mediated by stimulus hemifield and interstimulus interval (ISIs), with a greater tACS modulation for flashes presented in the left hemifield and for medium/longer ISIs. Regarding EEG results, we found modest electrophysiological evidence of alpha frequency modulation following stimulation, suggesting a short-term plasticity that is not captured by offline recordings. These findings suggest that mixed model analysis might help unveiling complex effects of tACS on perception that are mediated by low-level stimulus characteristics and inter-individual differences. Importantly, they provide novel evidence about the possibility of modulating perceptual sampling using tACS delivered at individualized alpha frequencies.

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Categorization demands modulate neural representations

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Humans can rapidly and automatically categorize objects suggesting that the categorization process is hard-wired and bottom-up. In this study we, nevertheless, examined if the level at which an object is categorized modulates its neural representation. We asked participants to categorize images either at the superordinate level (animal/non-animal) or at the basic level (bird/non-bird) while measuring their scalp electrical activity. As expected, participants performed better (faster, more accurate) in the superordinate than in the basic task, principally due to difference in performance when categorising bird images. To determine if object representations change with categorical level, we applied linear classifiers to EEG data and compared decoding accuracy between bird and non-bird animals when participants performed superordinate or basic categorization. We found that decoding accuracy was low and comparable for the first 200 ms but was subsequently better for the basic task. That is, the neural responses to birds and non-bird animals become more separable when performing basic-level than superordinate-level categorization. On the other hand, decoding accuracy between non-bird animals and vehicles was comparable in both tasks, indicating that the results were not driven by the 'target' and 'non-target' assignment to the categories, or by differences in motor responses. Representational Similarity Analysis further suggests that bird representations were more distinct than animal and vehicle categories during basic-level categorisation. We conclude that neural representations of objects are adaptively altered to the current task requirements.

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Predictive Control in Interception Tasks: Understanding the Angle-of-Approach and Curveball Effects

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In interceptive tasks, the trajectory followed by the target influences the kinematics of hand movements. Although it is generally accepted that online information underlies the control of action, there is still controversy over the specific nature of the information used to guide action. This study challenges the traditional focus on optical information alone, highlighting the crucial role of internal representations in coordinating eye and manual movements. Specifically, we examine the impact of predictive mechanisms on the angle-

of-approach effect and the curveball illusion during interception tasks. Fifteen participants were required to intercept a moving Gabor patch that included a drifting internal texture. Our findings show a robust angle-of-approach effect due to the kinematics of the target, and a strong curveball illusion effect due to the drifting stimulus in manual aiming. Interestingly, the viewing conditions mediate only the extent of the curveball illusion effect, indicating a differential reliance on intermediate estimated and predicted cues. To explain this discrepancy, we introduce a Linear Quadratic Gaussian (LQG) controller that accurately replicates the kinematic patterns observed based on different levels of internal uncertainty. Our findings offer a comprehensive and quantitatively grounded explanation of the dynamic interplay between internal estimations and motor control under visual illusions.

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Circular shape distortion illusions caused by adaptation of curvature detectors

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We conducted an experiment to validate an adaptation model of curvature detectors aimed at explaining the flash-induced circular shape distortion illusion. When circular shapes and their gradient counterparts alternated in flash presentation at 2 Hz, the circular shape appeared to transform into a polygon within 2-3 seconds, and its orientation was unstable. To account for this phenomenon, we proposed a model assuming a group of curvature detectors corresponding to the curvature of the circle. In this model, adaptation of these detectors leads to relatively larger outputs of adjacent detector groups with smaller curvature (straight lines) and larger curvature (angles), resulting in the perception of a polygon based on their combination. If this model is correct, we anticipated that after adapting to a stationary polygon of a specific orientation, observing the flash-induced circular shape distortion illusion would result in a perceived polygon with an stable orientation (position of straight lines and angles) different from the adapting stimulus. In the experiment, observers were presented with adapting stimuli of either two types of hexagons, with upper parts being straight lines or angles (experimental condition), or circular shapes (control condition), followed by flash stimuli to observe and report the shape of the upper part of the perceived polygon. As a result, more responses of polygons with orientations different from the adapting stimulus were reported in the experimental condition compared to the control condition. These results support the adaptation model of curvature detectors.
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Enhanced illusory color signals in individuals with reduced chromatic sensitivity

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Color perception relies on both the low-level spectral analysis of light reflected by an object and the high-level interpretation of retinal output. In this study, we investigated the relationship between these two stages of color vision by examining differences in the perception of illusory color signals and variations in chromatic sensitivity across a broad age range. Participants performed a color matching task by navigating a cursor through a color space diagram to select the color that best represented their perceptual experience of a physically gray stimulus, which appeared colored due to surrounding colored backgrounds. Additionally, individual chromatic sensitivity was assessed using a standardized color vision test. We identified a strong inverse relationship between participants' perceptual experiences and their chromatic sensitivities. The lower the chromatic sensitivity, the more saturated responses were assigned to the stimuli. Consistent with the known age-related decline in chromatic sensitivity, we also observed a robust age effect, with older participants consistently reporting more vivid color perceptions. Our findings suggest an interplay between low-level and high-level processing of color information, where post-receptoral gain is dynamically adjusted to compensate for sensitivity losses. This provides valuable insights into the potential mechanisms underlying bistable color perception.

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Effects of temporal delay on task performance and sense of agency in continuous tracking task

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Remote robotic operation technologies hold vast potential for applications in disaster response, medical surgery, and beyond. However, the use of general communication networks introduces the risk of temporal delay between the user's operating action and its outcome, including visual display. This delay is known to decrease sense of agency (SoA). Previous studies have focused solely on the impact of delays on SoA and task performance, while the relationship between task performance and SoA remains insufficiently explored. This study investigated the impact of temporal delays on task performance and participants' SoA using a task that simulated simplified welding operations requiring continuous control. Additionally, we analysed the progression of the relationship between SoA and performance. For this purpose, a line-tracking task for 38 participants under four delays (0, 300, 600, and 900ms) and no-control conditions was designed. The task involved using a PS5 controller to trace a moving line on a screen. Task performance was evaluated based on the time the cursor stayed within a 4 mm deviation from the line centre, and subjective assessments of SoA were collected after each trial using a 3-point scale: "completely in control" (full), "followed with a delay" (biased), or "felt like someone else was controlling" (no). Throughout the experiment, performance linearly decreased as a function of delay, with the 900ms delay condition resulting in performance levels comparable to the no-control condition. However, the subjective evaluations revealed a different pattern. The proportion of "no" ratings at 900ms delay did not reach the same level as the no-control condition. These findings suggest that, although performance and SoA are related, they may not be entirely mediated by the same underlying mechanisms.

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Temporal adaptation and savings to constant and varying visual feedback delays in a driving simulator

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Evidence of adaptation to constant visual feedback delays has been observed in a wide range of simple visuomotor tasks. However, when latency-induced visual feedback delays occur in more complex user-operated technologies, the delay is often not fixed at a single value but instead continuously fluctuates. Additionally, those who commonly experience these delays in these applied settings, such as online gamers or telesurgeons, experience the delay for an extended period of time over multiple sessions. In the present work, we explored how participants adapt to both constant and varying visual feedback delays in a driving simulator task. In the task, participants had to follow a line on the road as closely as possible while their steering inputs were delayed. We recorded a range of performance measures, including: spatial error, average car position, and self-reported subjective experience. In Experiment 1, we exposed participants to these two delay conditions for a single test session. We find that both groups recovered performance at a similar rate. The two delay groups also demonstrated after-effects consistent with temporal visuomotor adaptation. In Experiment 2, we exposed participants to these delay conditions across four sessions spaced one week apart. For both constant and varying delays, participants demonstrated faster adaptation rates in consecutive weeks, demonstrating savings. Additionally, both groups reported that their perception of the delay decreased across the four sessions, showing evidence of temporal recalibration. Together, these experiments demonstrate that adaptation supports recovery of performance and maintains a stable perceptual experience in conditions of repeated exposure to delayed visual feedback. The use of a complex task with a varying delay demonstrates that adaptation can support improved performance and experience in the type of task encountered in both consumer and industrial applications.
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EEG responses to the numerosity of objects in partially occluded and uncovered scenes

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When an object is partially occluded, its hidden parts are completed in visual perception, a phenomenon known as amodal completion. In partially occluded scenes, the number of hidden objects is underestimated compared to an estimation based on the density of visible objects and the amount of occlusion. It is still an open question at which level of processing this effect occurs. Here, we investigated this question using a passive viewing task in which observers viewed a partially occluded game board that was later uncovered to reveal its hidden parts. Concurrently, we measured the electroencephalographic (EEG) responses to the presentation of the occluded board and when it was uncovered using P1, N1 and P3 components. We varied the number of initially visible and uncovered game pieces on the board. We predicted that if underestimation of the hidden numerosity is a result of early perceptual processing, this would be observed in the activities of P1 and N1, while if it is due to higher level processes such as expectancy or confidence, it would be reflected in P3 activities. Our data showed that P1 amplitude increased with numerosity in both occluded and uncovered states, pointing to a link between P1 and physical stimulus features. The N1 amplitude was highest when both the initially visible and uncovered areas of the board were fully filled with game pieces, suggesting that the N1 component is sensitive to the overall Gestalt structure. Furthermore, we observed that P3 activity was reduced when the density of game pieces in the uncovered parts matched the initially visible parts, implying a relationship between the P3 component and expectation mismatch. Overall, our results suggest that estimating the numerosity of hidden items is influenced by high-level processing.
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From fixation to action: the interplay of task demands and object properties in multi-object selection

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Extensive research demonstrates that visual attention is selectively concentrated, necessitating ocular movements to acquire information from the environment. The 'Functional Visual Field' encapsulates this selective focus, which is influenced by the complexity of the targeted feature. Insights into the Functional Visual Field have primarily emerged from experiments using simplified stimuli in single-item search tasks. However, the role of subsequent actions performed with attended stimuli, such as collecting or organizing, has often been neglected despite their relevance in real-world scenarios. Our study aimed to address these gaps via a tablet-based task utilizing 2D LEGO® stimuli, thereby more closely simulating real-world objects. By integrating a designated drop area for post-selection actions (e.g., collect, sort, pile), we explored how search feature and task complexity affect eye movements and examined whether visual search mechanisms might be governed by broader principles, including both the initial selection and subsequent manipulation of objects. Participants were tasked to select items of the same color or same shape and subsequently drop them according to specified actions (e.g., collect, sort, or pile). Findings revealed more yet shorter saccades executed when targets were shape-matched. Saccadic endpoints analysis showed a symmetric search pattern across both horizontal and vertical meridians for shape searches, while color searches induced larger, predominantly horizontal saccades. Finally, the sorting task elicited larger and more frequent saccades compared to simple collecting, underscoring the influence of task complexity on eye movement patterns. Taken together, the results suggest that

color searches expand the attentional FVF, enabling the detection of near-to-far targets and promoting an efficient near-to-far pick pattern. Conversely, complex shape searches require a narrower FVF, leading to systematic, grid-like exploration.

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Supervised and unsupervised use of eye movement training in rehabilitation of hemianopia

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Sudden visual field loss often accompanies lesions along the visual pathways. It has been demonstrated that the pattern of exploratory eye movements is abnormal in the acute phase post injury. Although some patients may show spontaneous recovery, in majority of cases the abnormal dynamics of eye movements persists in the chronic phase. NeuroEyeCoach (NEC) is a compensatory rehabilitation training programme aimed at improving saccadic efficiency. It can be accessed online and has shown efficacy in improving outcomes such as faster search times and reduction in perceived disability. Here we report on the comparison of accessing NEC online, versus its supervised use in a clinical setting. 95 hemianopic patients accessed NEC online and 31 cases underwent supervised therapy in a clinical setting. Measurement of patients' performance before and after the intervention included reaction times in visual search, number of errors, and performance on a cancellation task. An activity of daily living questionnaire was also administered before and after the intervention to measure changes in subjective level of disability. Both groups showed faster search times, less errors, and improved performance on a cancelation task and a reduction in the self-reported disability after using NEC. Supervised group also showed significantly larger gains in search times and on cancelation task under supervised training than the home group. However, the improvements in the perceived level of disability were not significantly different between groups. NEC is effective in reducing the perceived disability and improving visual search in hemianopic patients when used supervised and unsupervised. The objectively measured gains are larger in supervised than home group, but this improvement is not extended to the subjectively measured outcomes and may relate to other factors such as increased attention improving task performance under supervision.

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Optimal visual gain for walking through virtual environments depends on the field of view

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Typical visual displays cover only a small fraction of the human field of view; even most virtual reality (VR) goggles are far from filling the entire visual field. How does this restriction affect the perception of self-motion induced by an expanding visual stimulus? We asked participants to walk at a constant speed of 1m/s on a treadmill in the center of a panoramic screen that filled 240 degrees of visual angle. We verified that they followed the instruction to look straight ahead by motion capture and eye tracking. On the screen, a scene depicting a cobblestone street framed by terraced houses was presented. The street extended straight ahead from the treadmill and the scene could move at varying speeds. Participants adjusted the speed of the scene such that they perceived it matching their walking speed. Part of the field of view could be blocked by an opaque gray overlay. When the full scene was visible, participants adjusted the visual speed to approximately twice their actual walking speed (1.9 m/s). This adjusted speed increased when a larger part of the periphery was blocked, reaching 2.3 m/s when only the central 10 degrees remained visible. When only peripheral stripes of 20 or 40 degrees were shown on each side, the adjusted visual velocity dropped, but reached 1 m/s only when the central 160 degrees were blocked. Our results highlight the role of central and peripheral vision for self-motion estimates and the importance to carefully consider the field of view during visual stimulation.

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Simultaneous regularity contrast and luminance polarity

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Texture regularity, as in for example the repeating pattern in a carpet, brickwork or tree bark, is a ubiquitous feature of the visual world. The perception of regularity has generally been studied using multi-element textures whose regularity is manipulated by the addition of random jitter to the elements' positions. We investigated the selectivity of regularity perception for the luminance contrast polarities of texture elements. Our psychophysical tool was simultaneous regularity contrast, the phenomenon in which the perceived regularity of a central target texture is altered by a surround texture with different regularity. Stimuli were composed of arrays of dark or white Gaussian blobs. Surrounds and center (test) stimuli had either the same, opposite or random mixtures of polarities. A matching stimulus with the same dimensions as the test was used to measure the perceived test regularity for a series of surround regularities that straddled the regularity of the test. Simultaneous regularity contrast was observed with all combinations of test and surround polarity. Simultaneous regularity contrast was bidirectional meaning that lower surround regularities increased while higher surround regularities decreased the perceived regularity of the test. We found that the magnitude of simultaneous regularity contrast was significantly greater for same-polarity compared to opposite-polarity tests and surrounds. With the random mixed polarity textures simultaneous regularity contrasts were opposite in direction to that found with the unmixed polarity textures. Our results are consistent with regularity being encoded by the degree of peakedness in the distribution of linear filter responses across spatial-frequency and orientation. We propose that simultaneous regularity contrast results from inhibition between surround and test filters with similar spatial tunings, with the inhibition being partially selective for luminance contrast polarity.

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Investigating numerical signatures with hierarchical Navon stimuli

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Number processing is characterized by numerical signatures which are related both to the features of the stimuli and task demands. Many of these signatures are related to either the magnitude being estimated, such as the size effect (i.e., small numbers processed faster than large numbers) or Spatial-Numerical Association of Response Codes (SNARC; i.e., small numbers are classified faster with the left than right hand), or relative difference between magnitudes, such as the distance effect (i.e., numbers further from a reference processed faster than those close). In the processing of hierarchical displays, such as Navon stimuli, different information can be present at different spatial scales (local and global). Thus, the same stimulus can produce different estimates, depending on what scale the participant is instructed to attend. We employed hierarchical stimuli composed of symbolic numbers (1, 4, 6, 9) both at global and local level. For example, a large "global" digit (e.g. 1) composed of multiple smaller "local" digits (e.g. 9). We then asked adult participants to either classify global (N=31) or local numerosity (N=30) as being larger or smaller than a reference number (5), while ignoring the other irrelevant spatial scale. We found faster processing of global stimuli (global precedence), consistent with typical Navon effects. Furthermore, when global and local information were identical (i.e. same digit), classification was faster. While both groups showed significant SNARC and distance effects, only the local group displayed size effects. Interestingly, local estimates were still faster even if the global number was only in the same range as the local (i.e. 1 and 4 or 6 and 9). Taken together, these results suggest that numerical processing occurs simultaneously at different spatial scales (even when task-irrelevant), but that local information is more subject to global interference.

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Does the Radial Bias influence fast saccades towards Faces

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Saccadic choice studies showed that humans initiate the fastest saccades towards faces compared to other visual categories such as animals, objects and scenes. These studies typically present images peripherally, along the horizontal meridian (HM). Our past work showed that face-specialized mechanisms engage most strongly along the HM due to the radial bias facilitating access to the horizontal structure of the face, known to optimally drive face detection and identification. We therefore hypothesized the set-up of past saccadic choice studies may have privileged the access to the horizontal structure of the human face, and therefore (partly) account for the saccadic advantage for faces reported so far. Thirty-six participants performed a saccadic choice task, targeting either faces or vehicles presented at 15° eccentricity along both horizontal (HM) and vertical meridians (VM). We expected to corroborate the saccadic advantage for faces along the HM where the radial bias facilitates access to horizontal content, and to see a reduction of this advantage along the VM. We found that the minimum reaction time to initiate a correct saccade (i.e., toward the cued category) was shorter for faces than vehicles overall. This advantage for faces was most prominent along the HM. These findings suggest that the reduced access to horizontal information along the VM could decrease the saccadic advantage for faces. We will investigate this phenomenon further by addressing its potential link to the radial bias and the horizontal tuning of foveal face recognition that we measured in the same participants.

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Unraveling the Monochrome Dunhuang Murals: Visual Imagery for Deeper Understanding

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There is a wide spectrum of visual imagery ability among individuals, with some having exceptionally vivid mental imaginations, while others may struggle to form clear mental images of visual stimuli (Pearson, 2019). These individual differences may contribute to the large variation in aesthetic appreciation of visual images. Here we aim to investigate the association between visual imagery ability and the aesthetic appreciation of Dunhuang murals, particularly the role of color in this association. We selected 24 high-resolution Dunhuang murals and created a set of monochrome versions by altering the color. A total of 41 Chinese undergraduate students (26 females and 15 males) with normal color vision were asked to view the monochrome images for five seconds and then close their eyes to visualize the images for 5 seconds. They were then instructed to rate each mural on two 9-point Likert scales based on two dimensions: like vs dislike and understanding vs. not understanding. After two days, they went through the same procedure for the original 24 murals. At the end of the experiment, we evaluated participants' visual imagery ability with Vividness of Visual Imagery Questionnaire. Participants demonstrated a 12.5% higher level of comprehension for the monochrome images (5.39 ± .78) compared to the original color versions (4.80 ± .76, $t = 4.94$, $p < .001$). Despite this increased comprehension, participants expressed a preference for the colored images (5.21 ± .58 vs 5.45 ± .59, $t = -3.61$, $p = .0010$). Further analysis revealed a strong correlation between visual imagery ability and the level of understanding for monochrome images ($r = .41$, $p = .010$), but not for color versions. These results suggest that (1) preference and understanding are separate in aesthetic appreciation of Dunhuang murals, and (2) visual imagery ability facilitates a deeper comprehension of the Monochrome Dunhuang Murals.
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Shattering the Ring: Statistical Learning Re-Shapes the Center-Surround Inhibition of the Visuospatial Attentional Focus

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To efficiently navigate and make sense of a visually complex environment, our neurocognitive system is capable of extracting and learning visual statistical contingencies to implicitly guide the allocation of spatial attention resources. Spatial attentional selection has been consistently associated to a "Mexican-Hat"-like distribution, wherein a shadow of sustained inhibition is projected around the center of the attentional focus to optimize the signal-noise ratio between task-relevant targets and interfering distractors. While it has been shown that experience-dependent mechanisms (e.g., reward) could shatter the inhibitory ring, the effect of statistical learning remains hitherto unexplored. To fill this gap, in a visual search psychophysical task, we mapped the visuospatial attentional profile. Participants (N = 26) initially directed their attentional focus toward a red target C. Following this, they were asked to indicate the orientation of a non-target C positioned at different distances from the red target. This condition allows to measure the behavioral expressions of the spatial profile of the attentional focus. We manipulated target spatial contingency to make it appear more frequently adjacent to the probe, i.e., in the inhibitory ring where we expected the lowest performance according to the Mexican-Hat attentional profile. Critically, this manipulation was crossed counterbalanced between visual hemifields and spatial quadrants, so that the stimulus array in each visual hemifield was defined by a manipulated vs. unmanipulated quadrant. We found that statistical learning engendered a reshaping of the attentional focus, transforming the "Mexican-Hat"-like profile into a non-linear gradient one, through a performance gain over the high probability spatial position. Noteworthy, the above effect appears to be asymmetric as it specifically unveils only within manipulated quadrants of the stimulus array, leaving – instead – unaltered the unmanipulated ones. These findings bring theoretical insights into how environmental visuospatial regularities orchestrate attentional allocation throughout a plastic re-weighting of spatial priority maps.

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Mixed Percepts During Binocular Rivalry Reflect Increased Cortical Inhibition According to Converging Physiological Evidence

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Binocular rivalry occurs when two incompatible images are simultaneously presented, one to each eye, so that they compete with each other to be the dominant percept. This fascinating dynamic visual illusion has been studied extensively as a window on to creative visual perception and conscious awareness. Traditionally, rivalry was characterized according to the dominant percept, but in recent years more studies focused on the percepts that occur during the transition from one image to the other. In 2016 researchers associated mixed percepts with a type of EEG signal thought to reflect cortical inhibition. We sought to replicate this result, and to generalize the finding to other measures and conditions. Perceptual reports were collected from 48 participants while viewing rivalry with orthogonal gratings (red in one eye and green in the other). Both dominant and mixed percepts were reported via button response. We measured whole brain MEG while participants viewed either tagged or untagged stimuli. In the tagged design, monocular stimuli flickered at 5 or 6.7 Hz. For this dataset, we replicated the finding that event-related intermodulation frequencies (1.7, 11.7 Hz) are greater for mixed percepts than for dominant percepts in multiple visual cortical areas. In the untagged dataset, results showed that alpha power peaks prior to a mixed percept, but alpha power is reduced prior to a switch-to-dominant. Connectivity analyses suggest a strong top-down source of the alpha signal. Finally, we compare the MEG results described above to those obtained when stimuli require inter-ocular grouping to experience global image perceptual dominance. As predicted, the later conditions elicited greater mixed percepts, along with enhancement of the physiological effects previously outlined. In conclusion, we consistently find that release from cortical inhibition accompanies the transition to a dominant percept in the context of controlled rivalrous competition, and perhaps during natural vision as well.
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Effect of element-lifetime and stimulus-duration on local and global motion processing: An equivalent noise study

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Human visual motion processing involves two-stages: activation of local motion sensors and global pooling of these responses. Using an efficient equivalent noise paradigm, we explored temporal integration of local and global motion information by manipulating both the duration (lifetime) of the local elements of a moving pattern and the duration of the global stimulus. Such manipulations elevate motion coherence thresholds, but it is unclear if this results from changes in local or global motion processing. Our participants judged if the overall direction of a moving dot pattern was clockwise or anti-clockwise of a randomly selected cardinal reference-direction. Our paradigm used an adaptive staircase to determine (a) the minimum direction offset required for reliable judgement of direction in a pattern where dots moved in similar directions and (b) the maximum tolerable directional noise (range of directions present) allowing participants to judge if a stimulus moved either +45 or -45 degrees of the reference direction. The two sets of thresholds allow one to infer both the accuracy of participants' (local) judgement of direction of single dots and the effective number of samples they globally average. We tested various dot lifetimes (33.36, 66.72, 133.4, and 266.8ms; stimulus duration 1000ms), and stimulus durations (62, 125, 250, 500, 1000, and 2000ms; dot lifetime 133.4ms), for dots moving at 10 deg/s. Longer dot lifetimes tended to enhance local direction processing (with performance plateauing around 133ms) without changing global integration (number of samples averaged). Participants who were poor at averaging exhibited generally higher local precision presumably because variable onset times introduces additional noise when averaging elements. Longer exposure durations increased the number of samples averaged (roughly doubling sample size over the times tested) but also modestly increased local noise, presumably due to increased local interference between elements.
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Major discrepancies in human and automated emotion classification (AFFDEX) for naturalistic facial expressions

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The quest for emotional artificial intelligence (AI) seeks to grant machines the capacity to recognize and respond to human emotions in a human-like manner. One approach to solving the recognition problem, which has attracted enormous financial investment, is the application of Ekman and Friesens' Facial Action Coding System (FACS) to identify what "action units" (AUs) are activated in a face and then convert these into emotion categories according to pre-determined AU combinations. This approach to emotion classification performs well using posed facial expressions. However, these exaggerated stimuli do not capture the range of facial behaviour encountered in everyday life. Naturalistic expressions are typically more subtle and complex than posed stimuli, and include cues to emotion other than morphological features. When testing the level of agreement between humans and machine coding (AFFDEX) in emotion classification for a large set of naturalistic expressions, we found very low agreement. At best, for happiness there was agreement between humans and AFFDEX in two-thirds of the cases, which was nearly double that for any other emotion. At worst, for sadness, anger, fear, and contempt, agreement was less than fifteen percent. Our comparison of AU activation profiles for human-assigned and AFFDEX-assigned labels reinforces that a FACS-based approach to emotion classification is poorly suited to drawing human-like conclusions from naturalistic facial expressions. These findings underscore the importance of designing AI systems that can adapt to the subtleties of human emotional expression for greater human-AI consistency. The findings also caution users of FACS-based methods of emotion perception about the limitations of these approaches in real-world scenarios.

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Overwriting Serial-Dependence: Learning Novel Cues to Update Internal Prediction Models of Object Weight

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Understanding how humans learn to adopt novel cues for perception and action has important implications for sensory substitution and augmentation learning. However, we know little about the mechanisms at play that support novel cue learning. One way to study this is by investigating how 'prior expectations' build up with increasing sensory experience. Prior expectations, or predictions, that an observer holds about an object feature, such as heaviness, can be inferred through measurements, such as grip force rate. In the absence of instantaneous heaviness-cues, observers rely more on recent perceptual experience (history cue), leading to well-established serial dependence effects. By studying how familiar (visual volume) and novel (line orientation) cues to object heaviness allow observers to scale their heaviness predictions, relative to history cues, we can assess how quickly novel cues are adopted and influence predictions for object interaction, compared to familiar cues. We tested participants on a serial object lifting task while recording grip forces. They could either rely only on previous experience (history cue), with no visual cue, or would get a familiar or novel visual cue. Using computational modelling, in each condition we fitted relative weights for the history cue vs the available visual cues. Preliminary results (n = 40) showed that the history cue was weighted significantly lower when either familiar or novel visual cues were present, suggesting that they were used to predict weight. The familiar visual cue had a significantly higher relative weighting than the novel cues. These results suggest that novel cues can be quickly learned to update internal models of object heaviness. Notably, while they show a stronger influence on object feature predictions than prior experience, they are not as efficient as familiar cues. Weight perception for action thus may be amenable to augmented learning by updating internal predictions with increasing experience.

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Visual perspective taking towards humans and social robots in a face-to-face interaction

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Visual Perspective Taking (VPT), the ability to spontaneously imagine an estimation of how another sees the world, underpins human social interaction, from joint action to predicting others' future actions and mentalizing about their goals and mental states. Due to highly customisable, repeatable behaviours, robots provide an ideal platform to investigate cognitive abilities such as VPT in tightly controlled face-to-face interactions. We contribute a novel experimental paradigm that robustly measures the extent that people take a human and robot's visual perspective during an interaction, by measuring how much a partner's perspective is spontaneously integrated with one's own. In our task, participants sit at a table with their partner to the left/right of them. Characters of varying orientation are presented either normally or mirrored. Participants judge whether the character is normal/mirrored. If a participant takes their partners perspective, the task becomes increasingly harder as the letter is oriented away from their partner, and easier the more it is oriented towards them - and this should be represented in reaction times. In our ongoing study participants are paired with another person, an inanimate humanoid robot, or an animate humanoid robot that engages with the task alongside the participant and performs socially interactive behaviours. We show (for the first time in a face-to-face interaction) that participants generally take other people's perspectives, but do not take the perspective of either robot. However, we find evidence that over time participants improve judgement times from the animate robot's perspective, demonstrating that VPT towards unfamiliar agents may be a more dynamic process than previously thought, facilitated by animacy cues, and task/social behaviours. Our study provides insight for designers creating cognitively penetrable robots. Importantly, our findings inform that people dynamically integrate other's viewpoints into their perceptual decision-making processes, and the behaviours/features of the interaction partner enable this integration.

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Motion Dazzle and the Motion-Induced Position Shift on cursor representation: behavioral effects in pointing movements

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A growing literature describes the effects of high contrast repetitive patterns on the perception of moving targets: “Motion Dazzle Effect” (MDE). Additional movement to those patterns moreover leads to the “Motion Induced Position Shift” (MIPS), where the target’s position is misperceived in the direction of pattern movement. Here, we investigated whether these patterns also lead to both MDE and MIPS if the pattern is placed on the cursor representation. For this, we used a goal-directed ballistic pointing task to 8 different target locations, placed on a circle around the starting point with target directions at 45° oblique and cardinal angles. The cursor was represented with a back-and-white striped pattern which was either stationary or moving with a constant velocity and direction within its circular envelope. The pattern was oriented at 0 deg (parallel), 90 deg (orthogonal), 45 deg (clockwise) or -45 deg (counter-clockwise) relative to target direction. Target and cursor were presented on a gaming monitor and movements recorded using a graphics tablet. We analyzed whether the cursor pattern resulted in deviations of the movement path and target-pointing errors (over-/undershoot and sideways deviation). We found that pattern motion led to directional pointing errors in the opposite direction of pattern movement, replicating the MIPS effect for cursor representation. More importantly we also found an effect of stripe orientation in the stationary pattern conditions. Particularly, the parallel relative pattern orientation led to overshooting the target whereas orthogonal pattern orientation led to undershooting. In this protocol, we observed no sideways deviation resulting from the pattern orientations. However, pilot data suggests that sideways deviations might be affected more by smaller relative pattern orientations and different target distances. Overall, the results indicate that for visuo-motor tasks patterns on both target and cursor can influence pointing behavior.

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Multimodal Person Evaluation: First Impressions from Faces, Voices and Names

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We cannot help but form a first impression every time we meet someone unfamiliar to us. While the existing literature has almost exclusively focused on facial impressions, we know from our everyday experiences that other aspects of the person can also inform the social judgements we make. Here, I first identify the most important and commonly used words and traits people use to describe their first impressions based on voice recordings, first names and multimodal information (face, voice and name), which reveals the underlying structure of these judgements. While the current literature on facial first impressions focuses on the evolutionary nature of such judgements, exploring other modalities introduces some key judgments related to social learning such as social class. I then use a series of multimodal rating studies to determine the relative importance of these three key sources of information – faces, voices, and names – to the overall perception of friendliness, confidence and intelligence. Crucially, all faces and voices used in these studies were naturally-varying and relevant to the context of first impressions, making them more representative of first impressions formed in everyday life. Despite the focus on faces in the literature, voices were the most important source of first impressions for all three traits. They were followed by faces, which still contributed significantly to the perception of friendliness, confidence and intelligence. Names had an overall small effect on social judgements, with their strongest influence seen for ratings of intelligence, likely informed by judgements of social class. This pattern of results persisted even when the presentation order of faces, voices, and names was systematically manipulated, providing further evidence for the remarkable role of voices in the formation of first impressions.

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Pupillometry as a no-report measure of perturbation detection in grasping

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Sensorimotor adaptation is a key process to continuously adjust actions in dynamic environments. Humans correct their errors both with the actor detecting the underlying systematic motor errors or, in an experimental setting, motor perturbations (explicit), as well as without detecting it (implicit), each with different specific properties. Here, our perturbations were visuo-haptic size mismatches in a grasping task. These mismatches followed two types of schedules (abrupt, sinusoidal) to investigate the respective contribution of (i) the perturbation magnitude and (ii) the error signal on detectability of these perturbations. N = 48 participants were asked to grasp cuboids of different lengths in a mirror-setup allowing us to present different sizes for seen and felt cuboids, respectively. We assessed perturbation-detection performance in a size-judgement task and analyzed maximum grip apertures as a measure of error-correction. We also measured pupil responses as a physiological no-report marker of perturbation detection that, if sufficiently sensitive, could allow experimenters to forgo explicit judgements that inevitably point participants towards the manipulation. We found that participants adapted their grip apertures to both abrupt and sinusoidal perturbation schedules, but more strongly for abrupt schedules. Detection performance was comparable between sinusoidally and abruptly introduced perturbations for the first few trials, but declined over time in “abrupt” blocks, consistent with the idea that reduced error signals following adaptation make it harder to detect perturbations. Additionally, we found a weak (negative) correlation of detection performance and error-correction. Pupil diameter also responded to perturbations in both schedules where larger diameters and faster dilation changes were related to larger perturbations and correct responses, but with a much less clear pattern compared to the size-judgement task. Thus, pupillometry is a promising approach in understanding the cognitive side of real-world motor behavior, but there is still need to validate its suitability as a predictor for perturbation detection.
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Decoding associative learning in human

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Understanding how past sensory experiences influence the way our brains process current or upcoming objects is essential for unraveling the neural mechanisms underlying perception. Previous studies have used multivariate pattern analysis to demonstrate that the neural representation of a current stimulus reflects traces of preceding stimuli. However, they have not provided insight into whether the same neural code is shared between past stimuli and the representation of current stimuli. To address this limitation, the present study employed a cross-decoding method to investigate whether neural activity associated with previous or upcoming stimuli is similar to the representation of current stimulus. We recorded neural activity while participants viewed sequentially presented images from different categories (Flower, Dog, Forests, Office). In two within-subject conditions, image presentation order either random or fixed. Specifically, Flower images consistently preceded Office images, while Dog images consistently preceded Forest images. To explore the influence of past experience, an algorithm trained to classify categories Dog versus Flower (previous objects) was tested on classifying Forest versus Office (current objects). Successful differentiation between object Forest versus Office by the algorithm would suggest Dog-like or Flower-like activity in the neural response to Forests or Offices. Similarly, predictive activity was investigated by training a second classifier to decode Forest versus Office (upcoming objects) and testing it on decoding objects Dog versus Flower (current objects). Significant classification performance in this case would suggest that the neural representation of visual objects contains predictive information. This study, currently in the process of data analysis, may provide insight into how past experience and the anticipation of visual objects are neurally implemented in the brain.

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Testing the color name of #TheDress in DNNs with various levels of blue bias

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The color of dress in #TheDress image has been named in various ways, such as blue/black, white/gold, etc., while the color matching result has reported rather continuous variation in its appearance. One of the sources of this variation is considered a bias of object color estimation called "blue bias," in which people perceive white objects under bluish illuminant as white despite the color of reflected light. Since this blue bias seems to develop through daily experience, it is difficult to manipulate in humans. Instead, we used an artificial neural network model to assess the color of #TheDress, after learning different levels of blue bias. A style transfer DNN was used to mimic the color naming procedure. The model learned relationships between photograph and objects' color labels, which were given as a map of color name for corresponding pixels. Two types of color labels were used; one type of label reflects the blue bias that naturally appear to humans, and the other type labeled the color of pixels and ignored the blue bias. Color-label images were generated with an in-house algorithm which utilized the result of a previous study on color naming. The validity of the color labels was evaluated by human participants before training the DNN model. By varying the percentage of blue bias images in the training set, we simulated differences in exposure to blue bias scenes. The color of #TheDress was tested after the training with natural images. The model was also trained to name the correct object color under different illuminant colors, like color constancy in humans. The result showed gradual changes in "color names" for #TheDress image with the blue bias ratio, suggesting a possibility that the relative exposure of blue bias scenes could cause individual differences in the perceived color of #TheDress image.
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Impacts of the peripheral optical flow generated by body sway during quiet standing

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Several vision studies on postural control have shown evidence for the contribution of both peripheral vision and optical flow. In the moving-room experiments, optical flow induced participants' postural sway and their sway synchronized with the cyclic room movements even though participants did not consciously perceive those movements. The moving-room experiments are therefore often used to investigate the functional relationship between optical flow (vision) and postural sway (action) in quiet standing. In our previous study using "static" visual stimuli, we focused on a likely visuomotor interaction during postural control and found an advantage of peripheral vision with optical flow generated by the body sway per se. The present study, using "dynamic" visual stimuli, aims to reveal the contribution of visual fields with optical flow generated by body sway. 27 healthy graduate and undergraduate students participated in this experiment. The sinusoidally expanding/contracting visual stimuli were presented either on a desktop display (DTD) or a head-mounted display (HMD). In such an experimental settings, quiet standing with DTD causes the optical flow due to the participants' sway, whereas when a HMD is mounted on the participants' forehead, optical flows are not produced because the HMD moves with the head. The use of HMD is therefore considered to be a setting that verifies the pure contribution of optical flow under any visual stimulations. In both settings, visual stimuli controlled the postural sway, replicating the previous finding of the moving room paradigm. However, the HMD did not show the advantageous control of posture under the dynamic stimulation to the peripheral visual field. These results suggest that peripheral optical flows generated by the participants' body sway effectively contribute to the postural control of quiet standing.

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Comparing confidence biases in decision about perception and general knowledge

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Recent studies on metacognitive abilities using confidence ratings found correlations across different decision domains, and suggested that metacognitive capacity is supported, at least in part, by a domain-general mechanism. However, these studies relied on self-report

measures, so it remains unclear whether these correlations originates from shared mechanisms for monitoring uncertainty or from response-related processes that map internal confidence states onto rating scales. Importantly, sources of uncertainty differ significantly between domains, such as sensory noise in perception and incomplete information in knowledge-based decisions. Consequently, monitoring uncertainty in these different domains may require different strategies, potentially leading to distinct confidence biases (defined as over/under estimation of uncertainty). In fact some lines of evidence point to opposite confidence biases in perceptual vs. knowledge-based decisions: whereas overconfidence is typical in decisions about general knowledge, recent studies using implicit, model-based measures have shown underconfidence in perceptual decision-making. This study investigates these biases further by employing a dual-decision method, in which participants are required to use confidence in a prior decision to inform expectations about subsequent choices. By modelling behaviour in this task, we can attain a principled measure of confidence biases relative to an ideal Bayesian benchmark. The results indicate that, unlike in perceptual decision-making, when people makes decisions from knowledge (such as deciding which of two countries has a larger per-capita gross domestic product) they underestimate the uncertainty of their knowledge by about half (95% CI [0.45, 0.76]). This underestimation, indicative of an overconfidence bias, contrasts with results from perceptual decision-making and may be explained as a sampling approximation of Bayesian models in knowledge-based tasks, which tends to predict overconfidence when samples are limited.
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Attention please! Or how to model human face saliency using convolutional neural networks

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Predicting where people look when presented with an image is a major challenge in psychology and computer vision and has been studied for decades. Behavioral experiments and computational simulations have shown that these locations depend on image properties in addition to their semantic content. While the vast majority of studies have addressed this issue using model comparisons limited to natural scenes, few have analyzed these predictions for emotional faces. We compared the regions of interest of eye fixations on emotional face images with LayerCAM saliency maps collected from pre-trained convolutional neural networks, as well as those collected from classical state-of-the-art saliency models: SUN, Walther & Koch and DeepGaze IIE. We assumed that state-of-the-art models mainly focus on the bottom-up energy content of the images, regardless of the task at hand. Therefore, we tested the simple effect of the task (biological sex versus facial expression classification) for otherwise identical emotional faces to test whether the aforementioned models effectively capture this dynamic of directed attention. Our results reveal a strong task effect for participants, modifying the regions of interest they attended to. We (1) replicate common results showing that current state-of-the-art saliency models fail to capture these task-dependent effects and (2) demonstrate that optimized artificial neural networks are capable modeling these, in a manner similar to human cognition.
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How head movements affect Functional Viewing Fields during visual search

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Visual search is often investigated only in a small region of the visual field and with constrained head movements. We asked, whether the visual search strategy is affected by allowing for more natural conditions with unconstrained head movements and a larger field of view. To test that we replicated and extended a visual search for the letter 'T' among distractor letter 'L's using a VR headset. Participants searched 'T's in three conditions: one replicating typical visual search experiments with head-restrained participants and a small (40 degree) search array, one with a small search array but an unrestrained head, and a much larger (80 degree) search array with unrestrained head movements. Visual search performance can be described by functional viewing fields (FVFs). The attentional FVF describes the region around fixation in which attention can be used to identify targets. The exploratory FVF describes the region in which someone might look next to keep searching for a target. The distribution of saccade amplitudes can be used to estimate the size of these FVFs. Saccades landing on the search target determine the attentional FVF, while those exploring the search array prior to this determine the exploratory FVF. Our results indicate that both the size of the search field and free head movement modulate FVF sizes. While FVFs did not change significantly between the restrained and unrestrained small array conditions, we did observe significant head movement and head-supported saccades. The large array produced significantly larger FVFs. The increase in attentional FVF size suggest that its estimation based on saccade amplitudes landing on target is not robust to changes in search array size. The increased exploratory FVF size suggests that some exploratory saccades are head-supported "long-shots". Our results suggest that we re-explore previous results in the presence of more ecologically valid oculomotor behavior.
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Meta-analysis of face and visual context interactions in emotion perception

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Long-standing theories, such as basic emotions theory, have argued that facial expressions signal core emotions (e.g., anger, disgust, happiness) in standard and consistent ways. However, the emotion perception literature now convincingly shows that the visual details which contextualise a face (e.g., body posture), known as visual context, alter how we perceive emotion from that face. The literature

also shows that faces alter how we perceive emotion from visual contexts. We used meta-analytic techniques to quantify these effects for the first time, as well as to understand what factors may moderate them. We searched across three literature databases to identify studies that investigated face and visual context interactions. Data for meta-analysis were available from 37 studies. Data were analysed using three-level mixed-effects meta-analytic models. We found large effects for both the influence of visual context on the perception of emotion from faces, and for the influence of faces on the perception of emotion from visual contexts. However, moderator analyses revealed that how clearly stimuli signal their intended emotion plays a key role in these effects. Overall, the influence of both faces and visual context were larger when they signalled different (incongruent) emotions (e.g., sad face on an angry body) than when they signalled the same (congruent) emotions (e.g., sad face on a sad body). Together, our findings clearly show that the integration of visual signals in emotion perception is influenced by multiple factors, including source (faces vs context), signal strength, and congruency. At this point, more sophisticated models are needed to identify how these factors interact, allowing us to determine how we weight these factors during emotion signal integration. Such models would give us the opportunity to provide important direction for technologies that seek to simulate human perception, such as artificial emotional intelligence.

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Oblique Effect and Search Asymmetry in Autistic and Non-autistic Individuals

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Background: Sensory symptoms are a core phenotype of autism, a neurodevelopmental condition with unknown etiology. Alterations in perception in autism have been attributed to the underuse of pre-existing knowledge and expectations (priors) in interpreting sensory information. Despite these strong claims, only a few studies have specifically investigated the use of natural priors, i.e., knowledge built on regularities in the natural environment, in autism. For example, the visual system is naturally tuned to favor horizontal and vertical lines over oblique ones (oblique effect), as these orientations are more common in natural and built environments. Objective: To examine whether and how autistic individuals use natural priors, testing the tuning of their perception to more frequent cardinal orientations in discrimination and visual search tasks. Methods: Fourteen autistic and fifteen non-autistic participants performed a 2IFC orientation discrimination task. Thresholds were measured for cardinal and oblique orientations. These samples of individuals, with new added participants (n=20 autistic and n=21 non-autistic), performed a visual search, localizing the hemifield of the target oriented either around 50° (near oblique) amidst 80° (near cardinal) distractors, and vice versa (near cardinal target amidst oblique distractors). Results: The orientation discrimination results revealed higher sensitivity for cardinal than for oblique orientations. However, the groups did not differ, and showed no interaction between group and orientation. In the visual search task, better discrimination was found for the near-oblique target among cardinals than for near-cardinal among oblique orientations (a search asymmetry effect). There was no group effect nor an interaction with orientation, although a tendency of greater search asymmetry was shown in autism. Additionally, a positive correlation between the tasks was noted in both groups. Conclusion: Our results indicate that autistic individuals use natural priors. Furthermore, the higher search asymmetry they show may indicate a higher susceptibility to noise.
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Visual and auditory discomfort: common explanations from natural texture statistics

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Images and sounds in the natural environment often evoke strong emotions in us. For example, beautiful fabrics and musical instruments appear pleasant, while rotten food or scratching on a blackboard cause unpleasantness or discomfort. These emotional responses may be triggered by specific features in the image or sound itself, rather than by the category of the object or event. Furthermore, they may be much simpler than the features required for object or event recognition. For vision, we have previously shown using images of various natural surfaces and noises that unpleasantness are strongly influenced by particular set of low-level image statistics, such as excessive power at intermediate spatial frequency bands, pattern isotropy at relatively high frequency bands, and disparate motion signals (Motoyoshi & Mori, 2016; Ogawa & Motoyoshi, 2020, 2021). Here, we measured auditory discomfort towards 185 natural sounds (e.g., clapping, metal scraping) and found that auditory discomfort also strongly depends on low-level sound statistics, more specifically, power at particular frequency bands in the 1st- and 2nd-order sound spectra. Considering the statistical regularities of images and sounds in the natural environment such as the 1/f spectrum, our results in both vision and auditory domains seem to suggest a common principle that stimuli that deviate from these regularities induce discomfort or unpleasantness. The finding supports the idea as proposed by previous studies (e.g., Wilkins, 1995), these irregular sensory signals force excessive neural processing in the sensory system which is optimized to process natural scenes and sounds, thereby generating neural signals that give rise to discomfort or unpleasantness.
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Coregistration of EEG and Eye tracking in Hybrid Search Using Deconvolution Methods

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In everyday scenarios, we frequently encounter the task of pinpointing a specific item amid distractions. For instance, imagine navigating a supermarket aisle to find any cereal from a list of preferred options. The demands of this hybrid visual and memory search task, where search is coupled with the simultaneous need to access and recall items from memory, represent significant cognitive challenges. To explore the dynamics underlying hybrid search, we conducted a study using concurrent EEG and eye-tracking measurements, focusing on fixation-related potentials (FRPs). Across two sites, 42 participants were asked to identify any of multiple memorized targets, with

varying memory set sizes (MSS). Our analysis investigated how different task components—such as task progression, target presence, and memory load—affect FRPs using linear model-based techniques. This approach effectively managed the temporal overlap inherent in natural viewing responses, allowing for a clearer disentanglement of the effects we sought to study. Additionally, we developed a specialized analysis tool in Python that facilitated exploration of alternative solvers beyond ordinary least squares, improving estimation accuracy and addressing collinearity issues. Ultimately, our findings demonstrate how integrating empirical and analytical approaches enables the differentiation of interacting neural processes while faithfully capturing the intricacies of real-world tasks.

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Feedback from medial parietal and ventral visual cortex to early visual cortex during mental imagery

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The ability to picture something in your 'minds-eye' in the absence of an external stimulus is referred to as mental imagery; an everyday task with surprising variation across individuals. One theory of mental imagery describes the phenomenon as perception in reverse, initiated in higher-level visual or parietal regions and culminating in a reinstatement of 'perception-like' activity in early visual cortex. While there has been some success in relating the perception and imagery of simple stimuli in V1, differences in the representational structure and time-courses across the visual hierarchy remains unclear. To investigate this, we first used representational similarity analysis (RSA) to quantify the overlap between image models (gist and LGN) and neural responses to familiar people and place stimuli during both perception and imagery. Using electroencephalogram (EEG), we found that the gist and LGN models correlated at distinct timepoints during perception that were mirrored during recall. These results suggest the emergence of 'perception-like' activity during imagery that developed with a similar, but delayed, time course to perception. Second, we used functional magnetic resonance imaging (fMRI) to compare visual cortex activity with the same visual models. In V1, we found a higher correlation with the gist model during imagery compared to LGN. In addition, a whole brain searchlight indicated that the gist model correlated with activity in a number of category-selective regions that have previously been linked with imagery, including the parahippocampal place area (PPA) and the medial parietal place area (MPA). Third, we used EEG-fMRI fusion to compare the time course of visual imagery representations within early visual cortex to those in higher-level category-selective regions (PPA and MPA). Fusion correlations with V1 activity occurred ~800ms later than higher-level regions, reflecting the top-down progression of mental imagery from category selective regions to early visual cortex.
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The consistency of peripheral appearance

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Peripheral vision is strongly limited by crowding, the deterioration of target identification in clutter. Target appearance is typically less clear in peripheral than central vision, and crowded compared to isolated conditions. However, to what extent (indistinct) peripheral target appearance is consistent over time is unknown. Here, we investigated (isolated and crowded) target appearance across multiple presentations. Twenty-two observers were presented with ten letter-like targets at 10° to the left or right of fixation. In one session, the targets were presented in isolation, in another session flanked. The sessions' order was counterbalanced across observers (Crowded-Isolated, Isolated-Crowded). All targets were presented with a probe (at fixation) initially consisting of one randomly selected target line. Targets were shown for unlimited time (gaze-contingent presentation). Observers' task was to compare the appearance of the target to the probe. When target and probe appeared different, observers adjusted the probe to match the target's appearance by placing and removing straight lines on the probe's 5×5 dot response grid. The captured appearance was used as a new probe for that target's upcoming presentation. If target appearance varied strongly (weakly) across trials, strong (weak) response variability would be expected. Results showed better performance (proportion correct) and higher response-target similarity for isolated compared to flanked targets, but only in the Crowded-Isolated order. Comparing the responses for each target (separately for the isolated and crowded condition) showed low response variability across all target repetitions (for both orders), suggesting that peripheral target appearance is stable over time. Crowding diminished target-response similarity, however, only in the Crowded-Isolated order, indicating that prior knowledge reduced the effect of crowding, and possibly reduced inter-trial variability. Taken together, we show how target appearance (despite its indistinctness in the periphery and under crowding) was stable across multiple presentations. However, prior knowledge seems to strongly affect (reported) target appearance.
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Orientation dependence of geometric optical illusions: 'up' is in the eye of the beholder

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It is well established that a number of geometric optical illusions are orientation-dependent. A prominent example is the Helmholtz square, where the orientation (horizontal or vertical) of the stripe pattern determines whether the square appears taller than wide or wider than tall. The perceived expansion is always perpendicular to the orientation of the stripes. Titchener's T has also been shown to be orientation-dependent. The illusion, namely the overestimation of the undivided line relative to the divided line in the T figure, is maximized when the undivided line is oriented vertically: the horizontal-vertical illusion and the bisection illusion accumulate in this

orientation. However, little consideration has been given to whether the reference frame for such orientation effects is gravitational or retinal, i.e. relative to the ground plane or relative to the orientation of the eyes of the beholder. We have conducted two experiments on the illusion strength in the Helmholtz square and in the T illusion. We independently manipulated head orientation (45° tilted to the left, vertical, 45° tilted to the right) and stimulus orientation (rotated 360° in steps of 22.5°). Our results show systematic shifts in the illusion maxima depending on head orientation, in the sense that illusion strength was maximized when the stimulus was optimally oriented with respect to the retina. We conclude that orientation effects in geometric optical illusions follow retinal rather than gravitational coordinates.

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Dopaminergic Control of Visual Change Prediction in Parkinson's Disease

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Navigating dynamic environments, human observers continuously sample information for impending actions. In a group of young healthy observers, we recently demonstrated that visual exploration is also driven by perceived potential for change (PfC) rather than visual saliency or implied motion alone (Roth et al., 2023). Here we extend these insights, probing neural mechanisms of PfC perception. We specifically examine Parkinson's patients, known for their striatal dopamine deficits, under conditions with and without dopaminergic replacement therapy to assess the dopaminergic system's influence on predictive processes in environmental perception. We hypothesized that dopaminergic therapy would alleviate PfC disparities observed in Parkinson's disease. The study engaged elderly, disease-free observers (60-85 years), and Parkinson's observers (59-83 years) to explore 80 real-world scenes previously rated for PfC by independent labelers. Scenes were presented in two conditions: static images for 10 seconds and as 5-second images transitioning into a 5-second dynamic video (frozen video condition). Conditions were blocked, and each scene was shown twice, to examine expectation modulation of the free-viewing task within scenes. Evaluating the first 5 seconds of gaze behavior, where the visual input was identical, showed that disease-free observers focused more on high PfC areas in the frozen-video compared to the static condition. In elderly observers, this exploratory behavior was limited to scenes containing humans or animals. Among Parkinson's patients, the ability to detect PfC remained stable under dopamine therapy but declined during dopamine withdrawal. Notably, in the off-medication state, the gaze patterns of these patients closely resembled those observed in static scenes, despite being previously informed of potential changes. Our findings underscore the pivotal role of dopamine in anticipatory environmental perception: Disruption of dopamine signaling in Parkinson's disease appears to impair not only the initiation of changes but also modulates visual change prediction in a free-viewing task.

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Effective connectivity of the cortical face-network through concurrent intracerebral electrical stimulation and frequency-tagged visual presentation

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The neural basis of human face recognition has been extensively studied for decades. The contribution of several face-selective brain regions in the ventral occipito-temporal cortex (VOTC; e.g., in the fusiform gyrus, FG; inferior occipital gyrus, IOG) has been established, but the functional organization of this cortical network remains largely unknown. In rare epileptic patients implanted with intracerebral electrodes in several face-selective VOTC regions, an original combination of frequency-tagging and direct electrical stimulation (DES) can provide unique information to address this issue. These depth electrodes allow us to stimulate a local node of the network while recording the functional activity of other implanted regions, with high spatial and temporal resolution. Here we report the case of a 34-year-old man, presented with 70-second sequences of natural images (objects with one face inserted every five images, at a 6Hz rate), while focal stimulation (1,0mA at 55Hz) was separately applied for 10s to four independently defined face-selective areas in the right and left VOTC (right and left lateral FG, right IOG, right anterior FG). Upon stimulation, face-selective neural activity was reduced or abolished both locally and at remote bilateral VOTC recording sites. These remote effects of DES were found in both postero-anterior (i.e., DES to lateral occipital cortex affecting fusiform face-selective activity) and antero-posterior (DES to fusiform gyrus affecting lateral occipital cortex activity) directions as well as across face-selective sites of homologous regions of the two hemispheres. Most importantly, this reduction was extremely specific to the face-selective response, as it did not extend to the general visual response (i.e., 6Hz and harmonics). Overall, these results shed original light on the functional connectivity of the human cortical face recognition network and pave the way for a more widespread and systematic development of this approach to reveal the functional and effective connectivity of human brain networks.

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Neural correlates of contour erasure as revealed by MEG

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Contour erasure describes the visual phenomenon that an object vanishes into the background after the object's contour was briefly adapted. Since its first discovery, the underlying neural mechanisms of contour erasure have remained elusive. Previous work has shown that such contour adaptation raised the contrast detection and discrimination threshold of a homogeneous target. To investigate the

neural mechanism of contour adaptation, brain activations during stimulus presentation in a Magnetoencephalography (MEG) superconducting quantum interference device (SQUID; Elekta Neuromag TRUIX) were measured in n=12 participants. Here, the target and pedestals were homogeneous crescent-shaped objects of 2° in width and 8.5° degree in length. The pedestals had five contrast level (from -30dB to -6dB). The target contrast was chosen according to previous threshold estimates. The contour adapters are two high-contrast crescent-shaped outlines matching the target and pedestal contours. All stimuli were centered at 3° eccentricity. On each trial, the contour adapters first flickered in counter-phase at 3.75 Hz for 1.5 s, followed by presentation of the target and pedestals. The pedestals were presented on both sides of the fixation point whereas the target was randomly superimposed on one of the two locations. The target and pedestals were presented for 83.3 ms after a short interstimulus interval (83.3 ms). The participants were instructed to indicate the location of the target (2AFC). We found that 1) the amplitude of event-related field (ERF) components at around 170ms after target onset increased with pedestal contrast, 2) the amplitude of this component decreased with contour adaptation; and 3) the amount of decrement was similar for all pedestal contrasts. Such results not only aligned well with the previous behavioral results but also reveal the time course of the neural processing underlying contour erasure and how such processing expanded across early visual cortex.
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Cross-modal serial dependence biases and the modulatory effect of task

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Serial dependence reflects a ubiquitous bias whereby current percepts are attracted towards past stimuli or past judgments. Although serial dependence affects virtually every aspect of perception, whether it could operate across different sensory modalities remains unclear. Here we address the existence of cross-modal serial dependence across vision and audition, and the potential role of task demands in driving such effects. We used a discrimination task of sequential numerosities, whereby serial dependence is induced by a preceding, task-irrelevant "inducer" stimulus. The inducer stimuli could be either sequences of tones or visual flashes. Additionally, the task could be either uni-modal (i.e., compare two visual sequences) or cross-modal (i.e., compare a visual and an auditory sequence). The results of the uni-modal visual task show serial dependence effects from both visual and auditory inducers, albeit with a stronger influence of the visual inducer stimuli. In the cross-modal task, however, we show a suppression of the uni-modal effects, and an enhancement of cross-modal effects, especially when considering the influence of audition on visual stimuli. These results suggest that (1) serial dependence can occur across different sensory modalities; (2) when the task involves cross-modal comparisons, cross-modal serial dependence effects are enhanced. Serial dependence seems thus to be modulated by the broader task context and by the relevance of information from different sensory modalities, in line with the idea that it originates from a relatively high-level brain processing stage.
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Psychophysical Measurement of Automatic Attention at Different Visual Eccentricities

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The assessment of Central Visual Processing has become an important component of ADHD diagnostic assessments. This study aimed to develop a measure of visual automatic attention for clinical application in supporting the diagnosis of ADHD. The participants were 30 children with ADHD (mean age = 10.6 years; SD = 3.28; 17 male) and 43 children without a diagnosis. All had vision corrected to normal. The measurement was carried out by presenting 99 Gabor function patches oriented at 90° and 1 patch starting at 135°. The test spot could appear at 0.4°, 2.0°, or 6.8° eccentricity to the fovea. The stimulation duration was 200ms. A staircase method was used to measure the orientation threshold for each eccentricity. For each eccentricity, 6 reversals were performed with the orientation threshold defined by the average of the last 4 reversals. Statistical differences were identified for all eccentricities (0.4° $F= 44.09$, $p<.001$; 2.0° $F= 12.18$, $p<.001$; 6.8° $F= 42.26$, $p<.001$). Results with orientations above 2SD of the control children were found in 19 children and below 2SD in 11 children with ADHD. Our results show that this measure of attention can be applied clinically. Children with ADHD show different altered eccentricity profiles, as well as lower and higher threshold results than controls, suggesting potential for differential diagnosis between attention deficit type ADHD and impulsivity type ADHD.
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Parafoveal preview effects during natural and accelerated reading

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Reading speed has been shown to play an important role in education outcomes. Externally imposed time constraints by means of text fading can enhance reading speed, without impairing comprehension rates, in children and adults with varying reading abilities and in different languages. Different cognitive and neuropsychological mechanisms have been proposed to underly the improvement in reading performance. However, the contribution of parafoveal processing to reading acceleration effects has not been considered. While visual acuity in the parafoveal region is reduced compared to the foveal region, parafoveal information is not completely neglected. During sentence reading the information at the right of the word currently under fixation is actively processed. Thus, parafoveal processing

during reading acceleration may become more efficient or increase its spatial extent over the future visual landing position as information to the left of fixation, which could have a potentially interfering or slowing influence, is progressively removed. In the present study, using the gaze-contingent boundary paradigm, we compared reading performance and parafoveal processing during natural and accelerated reading in two groups of participants. To this aim, we created a database of 175 sentences with related multiple-choice comprehension questions and pertinent answers. Sentences were controlled for the length, frequency, predictability, and position of the pre-target and target words. Parafoveal information of target words N+1 and N+2 after the boundary was manipulated using an identical (valid) or x-string masking (invalid). Behavioral results showed that participants in the reading acceleration group read faster, maintaining high accuracy levels, while preliminary eye-tracking data showed a modulation in word N+1 and N+2 preview position, suggesting that reading acceleration influences the strength and the spatial extent of parafoveal processing.

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The influence of eye movements on perceived tone frequency: exploring pitch-space associations through psychophysics

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Saccades are known to influence the perception of various visual features, such as size or numerosity. When used in action-perception studies, these simple, reproducible and effortless movements allow for repeated testing and calculation of psychometric functions. This contrasts with the more complex actions used in the few previous studies investigating the impact of action on pitch perception. For example, one of them suggested that participants' verbal reports of tone frequency indicated pitch overestimation (underestimation) when they were walking upstairs (downstairs). However, in the absence of a control condition, it is impossible to rule out alternative explanations involving verbal associations (i.e., “high” vs. “low”) or the usual representation of pitch along a vertical mental line. For instance, standing upstairs could be sufficient to overestimate pitch. To determine whether (eye) movements actually influence pitch perception, we measured the perceived pitch of pure tones in 28 participants using a psychophysical method (single stimuli). At the beginning of each trial, a central visual cue indicated the future location (top vs. bottom of the screen) of a saccade target. Immediately after this first cue, participants were presented with a tone of varying frequency that they were asked to judge. In a first experimental condition, they made a saccade to the target, whereas they maintained fixation on the center of the screen in a second condition. Points of subjective equivalence differed according to the location of the visual stimulus : pitch was overestimated (underestimated) when this stimulus appeared at the top (bottom) of the screen. However, our results did not show an effect of saccade execution. Discrimination sensitivity remained constant across all conditions. These findings suggest that activation of pitch-space associations is sufficient to bias tone frequency estimation, while movement per se is not necessary.

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Linearisation of a monitor for web-based experiments

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Running studies online has become increasingly popular but, for visual psychophysics, it presents some particular challenges due to the high precision that is often required in those studies. For many vision science studies the screen must have a linear luminance profile, rather than one following a gamma function as typically found on computer screens. This presents two problems for online studies. In the lab we would a) measure the luminance profile with a photometer and b) set the gamma value in the graphics card’s Look-Up Table (LUT). In web-based experiments, the browser doesn’t have access to the graphics card LUT and the participant doesn’t typically have access to a photometer. Here, we show how PsychoJS can solve the lack of access to the LUT by controlling the gamma of a browser window using WebGL shaders. We also demonstrate several methods to measure the screen gamma that are quick to run at the start of a study. With these problems solved many more vision science studies become amenable to experimentation online.
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Effects of aversive shock on perceptual learning in a virtual reality environment

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This study investigates two aspects of visual processing and perceptual learning: the impact of training on the human visual system's ability to integrate information across the visual field and the influence of aversive electrodermal stimuli on perceptual performance in an orientation averaging task. Through a ten-day training regimen manipulating the set-size of Gabor element arrays, we observe consistent degradation in orientation averaging performance with increasing set-size, with training leading to overall improvements but no interaction with set-size. This suggests that training-related enhancements likely operate at a post-integration and/or decisional stage of processing rather than at an early encoding stage. The second inquiry explores the effects of aversive stimuli on perceptual learning on orientation averaging performance. Our results reveal distinctive patterns in accuracy and response times under different shock regimes, indicating selective influences on specific facets of perceptual learning. Performance-contingent shock facilitates extended temporal windows for perceptual learning, while random shock conditions reduce learning-related improvements in accuracy. State anxiety levels, measured by the State-Trait Anxiety Inventory, show consistent anxiety elevation in the performance-contingent shock condition, suggesting a potential link between heightened stress and reduced response times. Unexpectedly, visual performance feedback, represented by a health bar, significantly influenced accuracy, but not response times, across all shock conditions. This unexpected impact of visual feedback suggests potential roles for attention and motivation in perceptual learning. The study introduces a novel virtual reality first-person shooter task to assess fundamental psychophysical performance, demonstrating promise for broader applications in cognitive and vision science research.

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Spatiotemporal characteristics of the stereoscopic anisotropy

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In stereovision, there is a well-known orientation anisotropy: disparity thresholds for sinusoidal corrugations of low spatial frequencies are significantly higher for vertical than for horizontal corrugations. While earlier studies have indicated that the response of the visual system is faster to horizontal than to vertical slanted surfaces, the spatiotemporal properties of stereoscopic anisotropy have not been thoroughly investigated. In this study, we estimate the strength of the stereoscopic anisotropy measuring disparity thresholds for drifting vertical and horizontal sinusoidal corrugations across various spatial (ranging from 0.05 to 0.8 c/deg) and temporal frequencies (ranging from 0 to 8Hz). Our findings indicate that disparity thresholds, as a function of the temporal frequency, exhibit a low-pass shape. Across all conditions, disparity thresholds are higher for vertical than for horizontal corrugations. Furthermore, the degree of anisotropy diminishes with increasing spatial frequency across all temporal frequencies, while it is more pronounced at lower spatial and temporal frequencies. We fitted a spatiotemporal local cross-correlation model (consistent with the physiology of the primary visual cortex) to our disparity thresholds for spatial frequencies higher than 0.2 c/deg. Our analysis uncovered that the width of spatial weighting function is slightly smaller for vertical than horizontal corrugations. However, the temporal characteristics remain similar for processing both orientations. Interestingly, fitting the model separately to low and high temporal frequencies, suggests the presence of two temporal mechanisms (one slow and one fast) in fronto-parallel stereomotion. Although the model, in the simulated conditions, replicates the human disparity thresholds for both orientations very well, it failed to explain the reduced sensitivity found for low spatial frequencies. A sensitivity parameter was also needed to account for both orientations, indicating a failure of the model to explain the stereoscopic anisotropy. Therefore, our analysis suggests that the stereoscopic anisotropy is probably caused by processing in the extrastriate cortex.
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The Impact of Scene Consistency and Orientation on Unawareness Visual Processing

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Scene consistency between targets and backgrounds enhances our understanding of the visual environment. Previous studies found that the scene consistency effect can be influenced by the orientation of objects and scenes. However, whether such relations between objects and background of a scene could be extracted in the absence of visual awareness remains elusive. To this end, we conducted two experiments using 2AFC (Experiment 1) and 2AFC-CFS (Experiment 2) to explore how scene consistency between targets and backgrounds (consistent, inconsistent) and their respective orientations (0, 90, 180, 270 degrees) influence responses with and without awareness. Given the unique processing advantage humans exhibit towards animate objects, we selected animals and furniture as target categories, set against indoor and outdoor backgrounds. Our findings from both aware and unaware stimulus presentations revealed a scene consistency effect and an animal advantage. Particularly in the unaware condition, we observed that image processing in inconsistent scenes relied more on the orientation of the target. Moreover, while inconsistent scenes slowed down the recognition of furniture, they did not affect the recognition of animals. Additional analysis of the angular differences between objects and backgrounds showed that, in consistent scenes (eg. Outdoor animals), the response times remained consistent regardless of angular differences. However, in inconsistent scenes (eg. Indoor animals), the reaction times were significantly faster when both the object and background orientations were at 0°, compared to other orientations. Our results indicate that: 1. The relationship between objects and backgrounds is processed at least partially in the early stages of visual processing. 2. In the 'unseen' condition, the processing of animal images remains largely unaffected by contextual regularities.
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A dynamic link between respiration and arousal

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Viewing brain function through the lense of other physiological processes has critically added to our understanding of human visual cognition. Further advances though may need a closer look at the interactions between these physiological processes themselves. Here we characterise the interplay of the highly periodic, and metabolically vital respiratory process and fluctuations in arousal neuromodulation, a process classically seen as non-periodic. In data of three experiments (N = 56 / 27 / 25) we tested for covariations in tidal volume (respiration) and pupil size (arousal). After substantiating a robust coupling in the largest dataset, we further show that coupling strength decreases during task performance compared with rest, and that it mirrors a decreased respiratory rate when participants take deeper breaths. Taken together, these findings suggest a stronger link between respiratory and arousal processes than previously thought. Moreover, these links imply a stronger coupling during periods of rest, and the effect of respiratory rate on the coupling suggests a driving role. As a consequence, studying the role of neuromodulatory arousal on visual processing may also need to consider respiratory influences.

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Spatial Layout and Composition: Related but Distinct Factors for the Aesthetic Appreciation of Natural Images

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Spatial Layout is an important concept in the literature on space and scene perception, while Composition is central in theoretical aesthetics, and art history, philosophy, and education. Both factors depend strongly on perceptual organization, and they could therefore have a similar impact on aesthetic appreciation. We aimed to reveal similarities and differences between both concepts in relation to aesthetic appreciation, by conducting an extensive online study (N=1300) with a diverse stimulus set of real-world images. We collected 7-point ratings for Spatial Layout, Composition, Order, Complexity, Pleasure, and Interest on 160 images of 80 manmade and 80 natural scenes. Participants rated either Composition or Spatial Layout of 40 images in two blocks, after they received a brief explanation with examples of good and bad composition, or clear and unclear spatial layout. In the first block they also rated either Pleasure or Interest, and either Order or Complexity. In the second block they rated the same images again on Composition or Spatial Layout and the remaining two concepts. Participants also completed questionnaires for basic demographics, art-experience, and personality. First analyses with Spearman correlations confirmed that Spatial Layout and Composition can be judged reliably (0.73 and 0.77, respectively) and were highly correlated (0.74), with some unexplained variance suggesting that they are not completely overlapping concepts. Composition was more relevant for Pleasure and Interest (0.77 and 0.70, respectively) than Spatial Layout (0.54 and 0.43, respectively). Order correlated more strongly with Spatial Layout (0.74) than with Composition (0.66), while for Complexity the correlations were both weak but had opposite signs (0.26 for Composition, -0.12 for Spatial Layout). Our findings indicate that Spatial Layout and Composition are related but distinct factors, with unique relationships to different dimensions of aesthetic appreciation. Future analyses of this dataset will provide insight into moderators of these relationships.
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Stepping over obstacles: Exploring the effects of surface properties and visual uncertainty

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This exploratory study (N=20) examined the effect of visual uncertainty (binocular vs monocular) and perceived unpleasantness and roughness of obstacles on stepping parameters during obstacle crossing. Roughness of the surfaces was manipulated by covering them with stones varying in size (small vs. large) and density (dense vs. sparse). Two additional conditions where the surfaces with large or small stones were reversed to present a smooth surface while maintaining a constant height were included. Participants' task was to step over the obstacles and to subsequently rate their perceived unpleasantness and roughness. Movements were recorded with a passive infrared motion tracker (Optitrack) with markers attached to the toes and heels of both feet. We explored spatial variables, e.g., clearance and step length (normalised to participants' leg length), as well as temporal variables, e.g., velocity. Participants rated surfaces with large or densely spaced stones as rougher and less pleasant than surfaces covered with small or sparsely spaced stones. Stepping parameters were affected by stone size and visual uncertainty, but not by stone density. Initially, leg clearance was higher in the monocular condition but decreased over trials to binocular level. Furthermore, step length increased over trials and was longer for obstacles perceived as unpleasant.
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The furrow illusion quartet (FIQ): A new display to explore the role of negative afterimages

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We present a new variant of the furrow illusion (Anstis, 2012) in which a quartet of fully opaque, untextured targets moves within two columns of thin, oriented line segments. Each column contains two circular targets (0.8°VA) that cycle, in opposite directions, upwards and downwards, from the midline to the screen edge, at a speed of 4°/s. The L/R columns (8°eccentric) contain lines (2°x .05°) oriented -45° and +45°, respectively. By default, the screen background is white, and the lines black, spaced 0.8° apart. An interactive demo is provided to modify display parameters. When the target luminance is close to the background, a strong illusion occurs, with upwards moving targets deviating outwards along the inducing lines, and downwards targets appearing to move inwards. As in the original effect, the illusion requires non-foveal viewing and inducing elements that remain stabilized relative to eye position. It is this latter characteristic that appears crucial. We argue that – at least with opaque targets – the furrow illusion arises due to the presence of negative afterimages generated by the inducing lines. Specifically, when an inducing target crosses a line, it releases a dynamic afterimage that fills the line contour, as in the aperture effect (Shiffrar & Lorenceau, 1996). Outside of the fovea – as positional resolution weakens – such afterimages appear to be treated as target features. A weighted vector sum of the local afterimage motion and the global target motion accounts well for the final percept (Tse & Hsieh, 2006). Display manipulations that eliminate afterimages – via contrast settings, relative depth, or flicker – also eliminate the illusion. Thus, interactions between elements physically present in the display are not sufficient to explain the illusion. To the best of our knowledge, this causal role for afterimages in generating illusory motion has not previously been reported.

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Active vision is timed to stabilise cortical representations for fixation-based memory encoding

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We explore the world by moving our eyes, briefly resting at a given location before saccading to the next. The duration of such fixations is systematically variable, with some lasting significantly longer than others. This raises the question why the brain decides to remain longer at some locations while novel information awaits elsewhere. Do longer fixations imply longer time needed for visual processing,

or do they occur to stabilise the neural code for downstream processes? To differentiate between these two hypotheses, we collected a large scene-viewing dataset (4,080 natural scenes, 5 participants) that combines magnetoencephalography (MEG) and eye-tracking, collected while participants carried out a semantic scene description task. Using multivariate analysis techniques and deep neural network (DNN) models, we find that for prolonged fixations, the visual neural representations are stabilised to support memory encoding. First, the change over time in MEG source activation patterns for longer fixations stabilised around the same time as for short fixations, and longer fixated image locations were more easily recognised by category-trained DNNs, speaking against the need for prolonged (recurrent) processing time in support of continual feature extraction. Second, fixation durations correlated positively with DNN-predicted memorability, and longer fixations appeared on objects later reported as part of the scene caption by our participants. Third, during the time of representational stability and towards the onset of a new saccade, we found increasing theta band activity in frontoparietal areas - a neural correlate of memory processing. In line with this, the decoding of the DNN-predicted memorability was strongest in the theta band. In summary, our behavioural, DNN model, and neural analyses provide coherent evidence that the brain's decision to remain at a given location is geared towards stable representations for fixation-based memory encoding - a novel perspective into the neural and behavioural dynamics of natural vision.
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Exploring the Interplay of Visuo-Spatial Working Memory and Oculomotor Control

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The saccadic global effect (GE) refers to the tendency for saccadic eye-movements to land at an intermediate location between a target and a nearby distractor. This effect is thought to arise from the averaging of activity in oculomotor neurons coding for the target and distractor locations. The content of working memory (WM) has been shown to influence saccadic behaviour, but the specific mechanisms underlying this influence are not fully understood. In the present study, we investigated the effect of visual and spatial WM content on the saccadic GE. In a first experiment, participants had to remember a colour and then make a saccade to either a singleton target or a target presented simultaneously with a distractor. Stimuli colours were manipulated so that either the target or the distractor could match the WM content. Our results showed that saccade endpoints were deviated towards the stimulus that matched the remembered colour, but only when the target was accompanied by a distractor. In a second experiment, we used the same task, but participants had to remember a spatial location that could either match the upcoming target or distractor location. Here, we observed an effect of the WM in both singleton and distractor conditions, but only when the target location matched the WM content. These findings suggest that the influence of WM content on saccadic behaviour depends on the type of information maintained in WM. When the WM content is visual, it biases saccades towards matching stimuli when two stimuli are simultaneously presented, consistent with a more 'strategic' explanation for the GE. In contrast, when the WM content is spatial, it influences the GE by modulating the relative weighting of the target and distractor locations in the oculomotor system. These results provide important insights into the mechanisms by which WM content shapes oculomotor control.

Rank Prize Lecture

Hide and Seek: Bringing Vision Science to Animal Pattering

Julie Harris[1]
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In the natural world, animals display highly specific patterns that are conserved across members of a species. These patterns are thought to enable animals to be hidden from predators, or sometimes to be easily seen. How is this done, and how well? A literature stemming from behavioural ecology has classified different forms of pattern, and studied how predators respond to changes in those patterns. Few studies have exploited the full power of vision science to understand how animal patterns might impact the visual systems viewing those animals. I will discuss how animals are patterned to either enhance or evade detection, and how vision science can give us fundamental insight to how and why these patterns are effective. I will start by reviewing the key strategies through which animal patterning is thought to evade detection through camouflage, and describe how vision science can be used to quantify the effectiveness of an example form of camouflage. Using a consideration of both the physical patterning and shape of real animals, I will describe research on counter-shading (patterning that results in animals having a dark back and light belly) that demonstrates the utility and effectiveness of this well-known form of camouflage. In contrast to evading detection, some animals (often toxic or unpalatable) display patterns of high contrast and bright colour, thought to enhance their visibility to ward off predators. I will review what is known about such warning signals in nature, and how they are studied. I will then describe how modelling of the first stages of visual processing, combined with experiments using real predators, suggests how warning signals might have specific effects on the brain that other patterns do not.

Thursday 29th August

Poster Session 7

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Eye movement perimetry in the pediatric population

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Purpose: To evaluate different objective methods for examining visual field healthy children and children with visual field defects due to central nervous system tumors. Relevance: Visual fields are commonly assessed using standard automated perimetry such as Humphrey Field Analyzer (HFA) or Octopus 900. These methods require active participation and gaze fixation which can be challenging, especially for children. Adding to the importance of good methods for pediatric examination is the fact that progression in visual field defect is an important indication for treatment with chemotherapy in children with inoperable in the optical tract. New methods are needed. Methods: Participants and patients were tested with standard ophthalmological tests including visual acuity, slit lamp examination, optical coherence tomography (OCT) and standard visual field examination as well as two eye movement based perimetry options developed by external companies (Reyedar and Bulbitech). Conclusion: Performance on eye movement based perimetry is age dependent and individual. Adaptations of the tests must be made to accompany the needs of children.
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Frontal Eye Field's Role in Visuomotor Learning: A Functional Connectivity Study

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The integration of visual processing with cognitive functions is a fundamental neural mechanism enabling the perception and interpretation of complex stimuli. This study explores the neural correlates of visuomotor learning by examining changes in functional connectivity involving the Frontal Eye Field (FEF)—a key node in the Dorsal Attention Network (DAN)—across a six-week visuomotor training regimen. Fourteen healthy participants engaged in daily 30-minute training sessions, aimed at refining eye movement coordination and visual attention. Functional Magnetic Resonance Imaging (fMRI) scans were conducted pre- and post-training to assess neural connectivity changes, utilising the CONN toolbox for analysis. Our methodological approach included three distinct comparative analyses: 1) functional connectivity of an FEF mask versus the rest of the brain; 2) network-level connectivity within DAN involving the FEF; and 3) a comparison to established fMRI findings related to DAN and FEF connectivity. Results indicated a significant post-training increase in functional connectivity between the FEF and specific cerebellar regions (Cerebellum 6 Left and Cerebellum 4_5 Left), suggesting enhanced communication with areas traditionally associated with motor control and now implicated in cognitive functions. Furthermore, an increase in activation was observed within the right occipital pole, consistent with enhanced visual processing. The study reveals that eye movement training strengthens visual cortex connectivity, offering insights into visual skill refinement relevant for targeted therapies.

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Percept durations of light flashes induced by microstimulation in visual cortex of blind human subjects

Richard Van Wezel[1], Youp van Oosterhout[1], Leili Soo[2], Fabrizio Grani[2], Marc van Wanrooij[1], Eduardo Fernandez[2]
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Intracranial microstimulation of the human visual cortex often induces light sensations called phosphenes, which could potentially be used to restore some form of vision in blind individuals. This study explores the minimum interval required for a subject to perceive two separate phosphenes from consecutive microstimulations (each lasting 167 ms) at various interstimulation intervals. We employed a 96-channel microelectrode system implanted in the occipital cortex of two blind subjects. The subjects were tasked with reporting whether they perceived zero, one, or two phosphenes while microstimulating, with one electrode, once or twice at different time intervals. We also examined the effect of adaptation by comparing perceptual discrimination and neural responses during the initial and subsequent trials within a block. Additionally, the influence of bimodal stimulation was investigated by pairing the electrical stimulation with zero, one, or two simultaneous auditory signals. Our findings reveal that the shortest interval needed to distinguish two phosphenes is approximately 300 ms for a stimulation duration of 167 ms, suggesting that the induced phosphene percepts persist beyond the microstimulation period. Moreover, neural responses diminished over time, indicating adaptation, and this decrease was associated with the necessity for longer intervals between stimulations to discern two phosphenes. No significant differences in neural or perceptual responses were observed when microstimulation was accompanied by varying numbers of auditory stimuli. These results will be discussed in relation to their implications for the development of neural prosthetics using phosphene vision to aid blind individuals.

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Spatial biases of overt attention and covert attention diverge during the free-viewing of videos

Yuqing Cai, Antonia F. Ten Brink[1], Stefan Van der Stigchel[1], Marnix Naber[1], Christoph Strauch[1]
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Attention deployment can occur either with eye movements (overt) or without them (covertly). However, it is not well-understood how these two modes of attention relate during free viewing, due to challenges in simultaneously measuring both. The current study attempts to investigate the relationship between spatial biases of covert and overt attention together during movie watching. Overt attention is tracked by where people are directly looking. The distribution of covert attention is represented by the amplitude of pupil responses to visual events in the movie, which is modulated by covert attention. Seventy-eight participants free-viewed multiple movie clips for thirty minutes while their gaze and pupil sizes were recorded. To infer the spatial allocation of covert attention, we adopted a recently published toolbox (Open-DPSM) that models how strongly the pupil responds to events across different visual field regions independent of stable low-level effects such as event eccentricity. We found covert attention to be biased to the upper right quadrant of the visual field, whereas overt attention was differently biased to the upper left during most video clips. Interestingly, the direction of the covert attentional bias changed as a function of the direction of the overt gaze across the movie clips. When the gaze was biased to the right

instead of the left visual field, which occurred in a minority of the movie clips, the covert attention bias was biased to the top left instead of the top right. This suggests a possible dynamic and compensatory mechanism in covert attention relative to overt gaze. In conclusion, the observed adaptability of covert attention to changes in gaze directions underscores the complex interplay between these two distinct modes of attention.

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The link between space and time along the human cortical hierarchy

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In humans, very few studies have directly tested the link between the neural coding of time and space. Here we combined ultra-high field functional magnetic resonance imaging with neuronal-based modeling to investigate how and where the processing and the representation of a visual stimulus duration is linked to that of its spatial location. Results show a transition in the neural response to duration: from monotonic and spatially-dependent in early visual cortex, to unimodal and spatially-invariant in frontal cortex. This transition begins in extrastriate areas V3AB, and it fully displays in the intraparietal sulcus (IPS), where both unimodal and monotonic responses are present and where neuronal populations are selective to either space, time or both. In IPS, space and time topographies show a specific relationship, although along the cortical hierarchy duration maps compared to spatial ones are smaller in size, less clustered and more variable across participants. These results help to identify the mechanisms through which humans perceive the duration of a visual object with a specific spatial location and precisely characterize the functional link between time and space processing, highlighting the importance of space-time interactions in shaping brain responses.
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Visually guided grasping in tool use: movement planning takes into account changes in tool orientation

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When grasping objects at different orientations, we automatically avoid awkward end-postures, reliably switching between ‘underhand’ and ‘overhand’ grasps as needed. This reflects the sensorimotor system anticipating the consequences of movements via internal models of the hand/arm/wrist. Here, we probe whether equivalent internal models underpin tool use, by examining whether awkward postures are similarly anticipated when the end-effector is rotated relative to the hand. Participants (N=20) grasped objects at various orientations (5-degree increments) in the frontoparallel plane, with the hand, and with tongs whose grasp aperture was rotated relative to the hand by 0, 45 or 90 degrees. The object was graspable along only one axis, resulting in two possible grasp orientations, 180 degrees apart. Participants completed three sessions on consecutive days. Movements were recorded using motion capture. Movement selection was reliable, and lawfully related to object orientation, in all conditions. The magnitude of tool rotation was mostly, but not completely, taken into account, such that awkward wrist end-postures were typically (but not entirely) avoided. Movements were substantially (~40%) slower with the tool than with the hand, however, and kinematic analyses suggested grasping movements with tools were more likely to be updated online than hand grasps. Thus, while changes in tool orientation are readily incorporated into movements, tool grasping appears less anticipatory, and more reliant on visual feedback, than hand grasping, suggesting internal models of tools are not necessarily equivalent to those of the hand. These findings have implications for designing devices such as prostheses, remote handlers, and laparoscopic-surgery tools.

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Prolonged fixation durations in color deficient observers

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Color vision deficiencies are quite frequent in men. However, effects on eye movement behavior have rarely been studied. We investigated eye movements during visual exploration of high-quality digital reproductions of 20 still-life paintings (Van Zuijlen et al., 2021) in normal and color deficient participants. We presented images of the original paintings in color and grayscale and modified both with the Eidolon factory (Koenderink et al., 2017), which diminished contour clarity while preserving the images' local structure but impairing object recognition. 23 color-normal participants and 19 with color vision deficiencies explored each image for 5 seconds and subsequently rating their liking on a 7-point scale. Eye movements were recorded using an EyeLink 1000. We analyzed basic oculomotor measures such as numbers and amplitudes of saccades, positions and durations of fixations and the extents of explored image areas (spread). We also explored scan paths, fixation heatmaps and the chromatic properties of the fixated regions of the colored originals. We found remarkable little difference in the fixation patterns of dichromatic and color-normal observers, likely due to the distinct delineation of objects in the original paintings. This held for the spatial distribution of fixations, but also for the color distributions of the fixated regions. Despite this, we observed a notable prolongation in fixation durations among color deficient observers, extending by an average of 20 msec for both, original and Eidolon images. Remarkably, the increase of fixation durations in the color deficient observers was also seen with the grayscale images. This study signifies a departure from traditional analyses focused on specific perceptual differences in color deficient individuals, highlighting a more general impact on visual exploration strategies. Our findings suggest that color vision deficiencies may lead to the development of compensatory mechanisms, altering how visual information is processed, irrespective of the presence or absence of color.

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Conscious Awareness Enhances Attentional Inhibition and Accelerates Attentional Sampling

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The rhythmic sampling of attention through oscillatory interactions within the fronto-parietal attention network has been regarded as an inherent, default attentional function, with the role of conscious awareness remaining largely unexplored. In the present study, we employed a technique known as critical flicker fusion (CFF) to investigate whether and how the conscious accessibility of attention-orienting cues could influence attentional sampling. Utilizing a high-temporal-resolution behavioral paradigm and EEG combined with the time response function technique, we revealed that both visible and invisible cues induced behavioral attentional sampling and reset neural connectivity between the frontal and right occipito-parietal regions, indicating that the fundamental aspect of attentional sampling operates independently of conscious awareness. However, visible cues not only elicited a more pronounced inhibitory behavioral effect and the corresponding alpha activity but also triggered faster behavioral attentional sampling (~8 Hz vs. ~4 Hz) and strengthened connectivity between the prefrontal and right occipito-parietal regions (alpha band vs. theta band), primarily driven by top-down processes. These findings provide novel evidence suggesting that the emergence of visual awareness influenced neural dynamic activity in the fronto-parietal attention networks, thereby modulating the attentional sampling process. This dynamic interplay of attention, modulated by conscious awareness, undoubtedly carries significant evolutionary implications, enabling humans to effectively navigate the ever-changing external world.
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The illusion of absence: Perceiving occluded space as empty

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Most objects in our visual environment are, to some extent, occluded, yet we nevertheless perceive them as complete. Even if objects become occluded entirely, we often do not experience them as absent but continue to represent them. However, some occluding events evoke the compelling impression that the occluded space is empty, i.e., an illusion of absence occurs. This illusion of absence provides a basis for magic illusions where things seem to appear out of nowhere or vanish into thin air, but could also contribute to road accidents (e.g. when the car's A-pillar occludes another vehicle or a pedestrian). This is a newly described phenomenon that can be demonstrated by different visual illusions, such as the floating pen illusion. Here, we will provide various examples of the illusion of absence and highlight its relevance for practical applications to prevent road accidents where another road user unexpectedly appears out of nowhere. In addition, we will provide preliminary data on an experiment investigating stimulus factors contributing to the illusion of absence. In some situations, revealing an object from behind an occluder might be perfectly in line with participants' expectations, while in other situations, it might lead to mere surprise, which would indicate the occurrence of the illusion of absence.
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Implicit learning of layout sequences in 3D

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People usually perceive surroundings as in the action space, so the representation of the world around the body possibly has sequential information related to action, i.e., spatiotemporal layouts. For example, attention shifts sequentially in a kitchen following the cooking procedure, such as to an ingredient, to a cutting board, to a kitchen knife, to a pan and so on. In this study, we examined whether spatiotemporal layouts can be obtained implicitly. We measured contextual cueing effect (CCE), learning effect of spatial layout in visual search displays in 3D space, which is known to be implicit (Shioiri et al, 2018, Scientific Reports). We investigated the CCE to letter arrangements presented sequentially in a 3D space surrounding a participant with a visual search experiment for 360 deg VR environment. There are four target locations among 24 locations. The participant searched four targets one by one. The first target was presented at one of the four target locations and the second target was presented as changed from the distractor there, when a response key was received indicating the first target detection. The detected target was replaced by a distractor at the same time, and only one target at a time throughout a trial. One trial finished when the participant found target four times. After 20 blocks of 10 trials (5 Old, 5New) in leraning phase, the order of target location was shaffled in transfer phase. If sequence is learned through the repetition, the CCE should decrease in the transfer phase while there should be no effect if only target locations are learned. The result revealed the reduction of CCE in the transfer phase and we concluded that sequential information could be included in 3D representations obtained through repeatedly action.

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Unveiling Biases in Automated Facial Action Unit Detection Systems

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Facial expressions are fundamental to human communication and can be deciphered systematically through the Facial Action Coding System (FACS), which breaks down expressions into discrete muscle actions known as Action Units (AUs). Recently, open-source automated AU detection systems like AFAR and OpenFace have become popular in research settings, due to their efficiency and cost-effectiveness. However, the performance of these systems and the extent of their biases remain unclear. Here, we use state-of-the art animation techniques and photo-realistic avatars, which afford precise control over facial expression and identity, to systematically examine these issues. We selected four avatars from the MetaHumans database, each differing in sex, age, and ethnicity, and animated them to display 11 individual AUs and 7 AU combinations, resulting in 72 distinct animations. We employed AFAR and OpenFace to track and analyze the AU's temporal dynamics, assessing the systems' performance using classification metrics and alignment methods. Our findings indicate that while both systems performed above chance (Mean AUC=65.5%), they were significantly below the ideal, revealing pronounced biases. Notably, we found significant effects of both the avatar's identity ($p<0.05$) and the type of AU ($p<0.01$) on performance. Performance discrepancies were particularly evident in the detection of subtle AUs and those performed by female avatars, with both systems showing lower true positive rates (TPR, $p<0.01$) and F1-scores ($p<0.05$), along with increased temporal misalignments in AU intensity detection (Rooted Mean Squared Error, RMSE, $p<0.01$). Furthermore, both systems showed a pronounced bias towards AUs typically associated with smiling expressions (False Positive Rate, FPR, $p<0.001$). Our results not only systematically unveil biases in current AU detection systems but also highlight the potential of advanced avatar and animation technologies in enhancing our understanding and evaluation of facial expressions.
Acknowledgements: This work was supported by DFG, Germany SFB/TRR 135 (grant number 222641018) TP C9 and S; and by the Research Cluster ''The Adaptive Mind'', funded by the Hessian Ministry for Higher Education, Research Science and the Arts.

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Memory matters: Unraveling serial dependence in visual perception

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Perception relies on ability to maintain congruent representations of the continuously changing visual input. However, this might also lead to biases when sequential stimuli are unrelated (often referred to as serial dependence). Most of the studies showing serial dependence do not require explicit memorization of stimuli, despite some hints that the strength and direction of biases might depend on the relevance of a stimulus for future behavior. To clarify this, we tested whether an explicit memorization cue might affect the strength of serial dependence. We modified a standard delayed orientation estimation task by introducing an explicit memorization cue on some trials. Participants (N = 18) were briefly presented with a Gabor patch and instructed to report its orientation by adjusting an oriented line displayed on the screen after a short delay. In 33% of trials, the fixation circle briefly changed color before the trial to indicate that the stimulus should be kept in memory and reported again after the next trial. The results showed the classical serial dependence effect: the response in a given trial was attracted towards the previous stimulus. Moreover, participants exhibited stronger attraction toward explicitly memorized stimuli. But whether or not the current stimulus was cued did not matter for the serial dependence from a previous (non-cued) item. These findings align with previous studies and suggest a more substantial serial dependence towards items represented with less uncertainty (more attended or more deeply processed). Interestingly, however, it goes against other studies that manipulated noise in the stimuli (e.g., by changing contrast) and showed that the noise/uncertainty on the current but not the previous trial affected the magnitude of serial dependence. This potential dissociation of effects that different noise/uncertainty sources might have on serial dependence contradicts simple Bayesian models and calls for more advanced theoretical models of this phenomena.
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Temporal Continuity in Visual Perception: Serial Dependence in Time Perception and Relationship with Working Memory

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Serial dependence is a phenomenon that biases the current perception based on recent history, creating temporal continuity in subjective experience. Whereas serial dependence has been found mainly in vision, in various tasks involving different domains like numerosity, color discrimination, and orientation, no previous studies have investigated the serial dependence of time perception in vision per se. The present study aimed to search for the effect of serial dependence in visual time perception using temporal interval duration discrimination and reproduction tasks. In the temporal discrimination task, participants were presented with three visual stimuli of varying duration and were asked to discriminate whether the second stimulus was longer or shorter than the third one. The first task-irrelevant stimulus was used to induce the hypothesized serial dependence effect on the perception of the second stimulus. In temporal reproduction task, participants were asked to reproduce an interval presented between two visual stimuli by pressing a button. Given the debate concerning the origin of the serial dependence effect, we also aimed to investigate the relationship between serial dependence and working memory capacity using a Corsi test. The findings provided evidence of serial dependence in visual time perception, and no relationship was found with memory retention capacity. Our results evidenced the relationship between time perception and the emergence of serial dependence; furthermore, the absence of correlation between the serial dependence effect and working memory allows us to hypothesize that a different memory process is involved, such as sensory memory.

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How realistic are AI-generated faces?

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The advent of diffusion-based models has taken the ability to generate fake content to a new level: with a simple text prompt anyone can create a convincing image of almost anything. Prior research has shown that humans are unable to reliably distinguish between real faces and faces synthesised using generative artificial networks (GANs), the precursors to diffusion models. We wondered whether diffusion models have also passed through the uncanny valley. To examine this question, we used the same 800 faces (400 real and 400 StyleGAN2) from Nightingale and Farid (2022). We synthesised a further 400 faces using Adobe Firefly, matching the original stimulus set in terms of diversity across gender, age, and race. In an online study, participants first see a short tutorial consisting of examples of synthesised and real faces. Following this, participants complete 96 trials consisting of a single face, of which a third are real, a third GAN-synthesised, and a third diffusion-synthesised (for each image type, faces are balanced equally in terms of gender and race). Participants have unlimited time to classify the face as "real" or "synthetic". Based on a small pilot data (N=13) overall accuracy is 50% (chance performance). Participants were more accurate at classifying the diffusion faces (60%) than GAN (45%) or real (49%) faces. We are now collecting the remaining experimental data. Early indications suggest that humans are limited in their ability to distinguish between real and synthetic images. The difference in accuracy scores implies the diffusion models are highly realistic but not yet as realistic as GAN. We also examined ChatGPT's ability to accurately classify these faces as real or synthetic. Somewhat to our surprise, with an accuracy of 65%, ChatGPT (v.4.0) outperformed humans, but still struggled to accurately perform this task, further emphasizing the photo realism of AI-generated faces.
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Investigating rhythmic visual perception with a display-wide resetting event: Evidence for lateralization of perceptual rhythms?

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It is controversially discussed if visual attention and perception are rhythmic or continuous. The common sampler hypothesis postulates a task-invariant and constant sampling rhythm of attention and perception. That is, phases of increased perceptual capacity might be interleaved with phases of poorer capacity, and the corresponding fluctuation might unfold rhythmically at approximately 7-8 Hz. One line of this evidence comes from visual psychophysics: A salient event is supposed to reset the ongoing oscillations to start at a specific phase in each trial. If performance (target detection or discrimination) is then probed at different intervals (inter-stimulus-intervals, ISIs) relative to the reset, oscillations should appear in the ISI-dependent performance. These timecourses are then Fourier transformed and permutation tests are used to determine if temporal structure is present in the performance timecourse. As the evidence is still equivocal, we used such a procedure to test the common sampler hypothesis in three experiments. A display-wide flash was used to reset putative attentional rhythms and we probed performance at each of two possible target locations with various ISIs after the reset (300-1100 ms). As the intended reset was designed to be global and should not favor sampling to start at one of the two locations, we predicted to observe the oscillation at 7-8 Hz. Across experiments, we obtained mixed results: Experiment 1 is in agreement with the hypothesis, but Experiment 2 and 3 are not (here, we also employed post-decision wagering to test for rhythms in metacognition). However, we observed oscillations consistently in the expected frequency range when only data from targets in the right visual hemifield were analyzed. We discuss this result in light of the debate surrounding the theory of rhythmic attention and perception and in light of evidence suggesting the lateralization of attentional resources.
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The Speed of Learning: Effect on Category Structure and Post-Acquisition Performance

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Category learning is an important cognitive process enabling individuals to classify stimuli into meaningful groups based on shared perceptual and semantic features. However, people acquire new category representations at different speeds. Some individuals are "fast" learners, acquiring categories in relatively few trials whereas other individuals are "slow" learners, requiring more training to reach the same level of categorization performance. To assess the category structure of "fast" and "slow" learners, before and after training, we employed PsiZ, a machine learning tool, to generate a two-dimensional psychological embedding (i.e., mental representation) based on participants' judgments of image similarity. In the first part of the study, 76 participants learned to identify four species of warbler (Prairie, Townsend, Magnolia, Cape May). Training continued until participants were able to identify the four warbler species with 90% accuracy. Following the initial session, participants were categorized as "fast" (top 33%) and "slow" learners (bottom 33%) based on the number of training trials required to achieve the 90% accuracy criterion. In the second part of the study, participants returned to the lab after 48 hours for a recognition test where they were asked to categorize novel images of the four warbler species. We found that "fast" and "slow" learners did not differ in the accuracy (means: "fast" learners = 0.892; "slow" learners = 0.889) nor the speed (means: "fast" learners = 1431 ms; "slow" learners = 1513 ms) of their categorization. In contrast to the behavioral findings, the PsiZ results showed significant disparities in the group's mental structures before and after training. "Fast" learners exhibited a notably distinct psychological embedding, demonstrating superior differentiation among warbler species even prior to training as opposed to "slow" learners. While the psychological embeddings of "slow" learners were less distinct, their post-training categorization reaction time and accuracy matched those of "fast" learners.

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The Effect of Distance on the Overestimation of Gaze Endpoint Eccentricity

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A widely known result from gaze perception research is the overestimation effect that gaze endpoint eccentricity is seen farther to the side than it actually is. As gaze endpoint must be a joint function of gaze angle and distance, the influence of distance on judgments was examined. With photographed models and the classic analysis, the overestimation of gaze endpoints at short distances turns into almost perfect perception at larger distances. This was true when gazing was done with the eyes only (head straight relative to observer) and with the head only (eyes straight relative to head). However, when the data were analyzed using the new triangulation approach, two components in the judgments could be separated: (a) a slope and (b) an intercept. The new analysis indicates that the overestimation of gaze angle (slope) is very moderate, and that the strong overestimation in gaze endpoints is mainly due to the intercept, which is a constant bias that depends on the gaze angle, but not on the distance. Further experiments indicate that the intercept effects are confined to 2D-pictures of lookers and are not observed in physical 3D lookers. The results are interpreted with reference to the distinction between picture space and physical space.
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Assessing cortical visual field loss across the visual field

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With advancements in ocular therapy, we need to understand how eye disease and recovery affect cortical function. Typical fMRI approaches to measuring cortical sensitivity across the visual field often lack applicability to low vision patients because they require good fixation and measure small visual field regions with a restricted range of stimuli. Here, we propose a novel approach for detecting changes in cortical sensitivity across the visual field. We recruited seven normal-sighted individuals (29.6±4.7 years) and one individual with simulated vision loss. By combining population receptive field mapping with a contrast sensitivity task during fMRI, we assessed changes in cortical contrast sensitivity up to 20º eccentricity. We estimated visual field loss in the primary visual cortex by analysing cortical contrast sensitivity across various spatial frequencies (0.3 and 3 cycle/º), eccentricity and visual field quadrants. To quantify contrast sensitivity, we took the slope of a square root function fitted to stimulus contrast responses (7.5, 42.2, 60, and 100%). We found variations in cortical sensitivity across visual field locations, with higher sensitivity to high spatial frequencies in central locations (0.5-2.5°: $p=0.005$; 2.5-4.5°: $p=0.013$) and to low spatial frequencies in peripheral locations (9.5-15°: $p=0.004$; 15-20°: $p<0.001$). Sensitivity was also greater along the horizontal versus vertical meridians ($p=0.001$) and along the lower versus upper vertical meridians ($p=0.006$), regardless of spatial frequency. Crucially, these effects were significant at the individual level, revealing high sensitivity of our approach. We also detected sensitivity loss between 3-8º for a simulated scotoma in that location. Our method can detect variations in cortical sensitivity across a large expanse of the visual field at an individual level, providing valuable tools to detect subtle changes in cortical sensitivity in patients. This could improve our understanding of ocular pathology and therapeutic impacts on signalling from the retina to the visual cortex.
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Peripheral crowding is invariant under different luminances

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Peripheral crowding refers to the difficulty in recognizing objects in the periphery when these are surrounded by clutter. Crowding impacts tasks like reading, search, and driving. The luminance of the environment also influences these tasks. However, the possible interaction between crowding and luminance remains not well understood. Here, we studied the underlying mechanisms driving peripheral crowding by measuring crowding magnitude and crowding extent across different luminances, ranging from scotopic to photopic levels. A total of 10 participants reported the orientation of the gap in a target Landolt-C (height 2o, positioned at 10° eccentricity and shown for 150ms). This target Landolt-C was either presented alone or flanked by four equally-sized Landolt-C's placed at one of five distances. Participants responded by adjusting the orientation of a centrally-presented reference Landolt-C. Goggles equipped with neutral-density-filters were used to manipulate stimulus luminance (five levels, ranging from 0.02 to 200 cd/m²). Participants' perceptual-error was defined as the difference between their response and the actual orientation of the target. Crowding Magnitude was defined as the perceptual error for a flanked target divided by the perceptual error for the isolated target and determined separately for each participant at each luminance and target-flanker-distance condition. Crowding extent was calculated by fitting a hinged line to the perceptual errors. Crowding magnitude and extent were both measured for flankers with either no gap, a gap at each individual's luminance-specific acuity threshold, or a suprathreshold gap. Results showed that crowding magnitude was similar under all luminance and gap conditions (no-gap: BF10=0.72; threshold: BF10=0.13; suprathreshold: BF10=0.28). At all luminance levels, crowding magnitude monotonously decreased as target-flanker-distance increased. Moreover, luminance did not affect crowding extent (no-gap=0.55, BF10=0.30; threshold=0.60, BF10=0.34; suprathreshold=0.62, BF10=0.18). The invariance of crowding magnitude and extent supports that the same mechanism is responsible for peripheral crowding under both scotopic and photopic lighting conditions.
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The effect of non-visual cues on estimating travel distance using peripheral or central optic flow

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Continuously evolving modes of moving people (e.g., driving cars, virtual reality, flying in space, moving walkways, etc.) challenge the brain's self-motion processing ability. Previous research from our lab (McManus et al., 2017) has shown that optic flow presented in the far periphery (from 90° to 110°) results in people feeling they moved further than when the same motion was presented full field or in only the central field. Although others have shown that non-visual cues are generally weighted higher than visual cues when estimating travel distances, it is unknown how non-visual cues might affect the use of optic flow in the far periphery. Here, we used a large-field edgeless display to either visually "move" participants while they were physically stationary, performing a blind walking task on a treadmill, or visually "moving" while walking on a treadmill. Optic flow was presented either full field, in the central ±20°, or in the far periphery (from 90° to 110°). Participants judged travel distances by stopping at the location of a previously seen target (Move-To-Target Task) or adjusting a target to indicate the distance of a previous movement (Adjust-Target Task). Preliminary results show that in the Move-To-Target task, peripheral optic flow led to higher gains (perceived travel distance / actual travel distance) than the central field and full-field conditions during both the visual-only and visual-and-treadmill conditions. In the same task, the blind walking condition also led to higher gains than the visual-only or visual-and-treadmill conditions. In the Adjust-Target task, there were no significant differences between conditions. These findings highlight the importance of the far periphery in self-motion processing and emphasize the importance of multisensory processing.

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Do stimulus history effects in color perception depend on distal or proximal stimulus properties?

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Color perception is often biased towards the average color of recently seen stimuli in delayed matching paradigms. It is unknown whether such stimulus history effects are determined by distal or proximal stimulus properties. We investigated whether delayed color estimates are biased towards the average surface reflectance (distal property) or the average chromacity (proximal property) of the stimulus set. Delayed color estimates were collected for circular stimuli (duration 300 ms) in a 2IFC task. A reference stimulus was presented in the first interval, followed by a test stimulus after a 1-second delay. The reference had one of three surface reflectances varying from blueish to greenish, simulated under one of three daylight illuminants (7800 K, 6500K, 5700K). The display background had the chromaticity of the illuminant, which varied across trials. On each trial, observers (N=10) indicated whether the second stimulus appeared bluer or greener than the first. Points of subjective equality were determined from psychometric function fits to the proportion of "greener" responses. Whether the color match for each reference was biased towards the mean reflectance (reflectance prediction) or mean chromaticity (chromaticity prediction) of the stimulus set would reveal whether the underlying mechanisms operate on distal or proximal stimulus properties. Delayed matches were biased towards stimulus history. The bias was not explained by mean chromaticity alone, but also depended on mean reflectance. We quantified the "reflectance bias" with a reflectance learning index, ranging from 0 (consistent with the chromaticity prediction) to 1 (consistent with the reflectance prediction). This index varied between 0.2 and 0.6 and correlated significantly with individually characterized color constancy, indicating that color constancy mechanisms were involved in bias formation. In conclusion, biases in color perception due to stimulus history are not fully determined by the proximal stimulus but are also influenced by inferred distal stimulus properties.

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Social perception from faces and bodies

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Despite the primacy of the face in social perception research, people often base their impressions on whole persons (i.e., faces and bodies). Examining impressions of whole persons is therefore crucial for a completer understanding of social perception. Yet, perceptions of whole persons remain critically under-researched. We address this knowledge gap by obtaining judgements of whole persons on various fundamental social attributes (e.g., competence, warmth, status) and testing the relative contributions of faces and bodies to each judgement. Specifically, we quantified the variance in perceivers' judgements explained by faces and by bodies. Results show that faces and bodies contribute different amounts to particular social judgments on orthogonal axes of social perception: bodies primarily influence status and ability judgments whereas faces primarily influence warmth-related evaluations. This suggests that perceivers may find faces and bodies differentially informative for different kinds of social judgements, perhaps due to differences in signal. That is, bodies may simply provide more information about ability, dominance, or status because body size and shape convey physical formidability, posture foretells impending action or threat, and clothing can reflect wealth and status. By contrast, the face may be better suited to communicating warmth or trustworthiness, given those attributes' large overlap with emotion expressions. To preliminarily test this explanation, we tested faces' and bodies' contribution to accuracy (as accuracy requires signal) in perceptions of one status-related attribute: social class. Perceivers judged social class from images of whole persons, bodies, or faces. Results showed that perceivers who could see targets' bodies (i.e., judged whole persons or just bodies) showed greater accuracy than those who judged only faces, indicating that bodies contain more signal to individuals' social class than faces do. Altogether, these findings highlight the importance of going beyond the face to fully understanding processes and outcomes in person perception.

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The effect of stress physiology on duration and contrast perception

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The perceived duration of stressful or threatening stimuli, which induce psycho-physiological changes, is typically overestimated. However, it remains largely unknown whether the effects of stress are confined to the aversive event that triggered them or if they persist after the event has ceased, and what causes this perceptual duration overestimation. This study investigates the role of perception in stress-induced temporal biases in the millisecond to second range. We assessed the impact of individual physiological reactivity to a stressful laboratory procedure on (i) the duration perception of short, emotionally-neutral visual stimuli and (ii) low-level visual processing, such as contrast perception. We monitored multiple stress-sensitive biomarkers, (i.e., salivary cortisol and pupil size) and assessed participants' performance in duration reproduction tasks and contrast discrimination tasks during distinct phases of the physiological stress response. Additionally, we explored phasic pupillary dynamics as subjects judged the duration of stimuli. Our results show that participants exhibited enhanced contrast perception and tended to overestimate the duration of stimuli after stress compared to control conditions. Specifically, the impact of stress on duration perception was strongest 10 and 30 minutes after the onset of the stress manipulation. Notably, these effects were observed only in participants who exhibited medium cortisol reactivity to stress, but not in those with the lowest or highest reactivities. The findings might suggest that stress physiology alters the perceived duration of a visual stimulus by modulating low-level visual processes involved in encoding its non-temporal features, such as contrast. These effects seem to occur only under specific physiological reactivity ranges and within a defined time window following stress onset. Additionally, this study offers an example of an analytic approach to investigate pupillary responses to subsequent brief events occurring at variable timings.
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Emerald isles versus emerald cities: The role of greenery in psychological judgements of environments

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Exposure to nature is generally assumed to be more beneficial for behaviour, health and well-being than exposure to urban environments, even when exposed to images only. However, little is known whether observed benefits are due to environment type per se or rather to differences in low-level visual properties (e.g. colour) and higher-level psychological judgements such as an environment's aesthetic appeal, fascination or comfort. Before tackling this question, we first needed to understand how liking, fascination and comfort vary within and across environment types. Using spatial multi-arrangement methodology to compare efficiently large numbers of stimuli, we asked 18 participants to rate 46 nature and 46 urban images for their similarity in liking, fascination and visual discomfort, with urban and nature stimuli pair-matched for the amount of greenery they contained. Representational similarity analysis revealed that liking, fascination and discomfort showed considerable variation in judgements both within and across environmental categories. An empirical model of image similarity (free of environmental dichotomy assumptions) was a better predictor of the three factors than an empirical naturalness model (i.e. how natural each image was perceived to be) or two theoretical models (one based on the amount of greenery in each image and the other on a binary, i.e. nature vs urban, environmental categorisation). These findings suggest that neither greenery nor a nature/urban distinction underpins psychological judgements about environments with regard to their aesthetic appeal, (dis)comfort or fascination. Future investigation into what makes an environment beneficial should therefore try to avoid a-priory categorisation of environment type.

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The Leuven Orthogonalized Art Dataset (LOAD): A Multidimensional Art Image Set for Aesthetic Appreciation Research

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The intricate interplay between visual art, aesthetic appreciation, and human cognition has long captivated artists and scientists. One difficulty of this line of research is that artworks possess many dimensions that influence aesthetic appreciation. Lack of control of certain dimensions or the assumption that they have no effect may cause bias in data interpretation; however, manipulating only one or two dimensions and setting others as constant may fail to represent the natural art-appreciation environment. In response, we developed an image set specifically aimed at experimental control over as many relevant factors as possible to achieve a balanced image set. The image set, Leuven Orthogonalized Art Dataset (LOAD), controls and orthogonalizes factors related to the aesthetic experience, including style, content, emotion, liking/beauty, and fluency. Each artwork in the image set was annotated by 50 participants on measures of pleasure, fluency, interest, liking, emotion, and familiarity. This careful annotation process also aims to disentangle the often-ambiguous interrelations among internal cognitive states such as fluency, pleasure, interest, liking, and emotion. By providing orthogonalized and refined insights into these factors, our image set opens new avenues for exploring the complexities of aesthetic appreciation and demonstrates the potential for use not only in behavioral experiments but also in the neuroscience field. Embracing a multifactorial design, the image set invites researchers to continue exploring the timeless inquiries into the essence of beauty and the nature of aesthetic appreciation.

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Towards Visual Acuity Estimation from Eye Movements

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Visual acuity, the capacity of the visual system to resolve spatial information, is a fundamental measure of great significance for both patients and eye care professionals. While optotype recognition tests (like Snellen and LogMAR) have long been considered the benchmark for assessing visual acuity, recent research has highlighted limitations associated with this method, prompting the exploration of alternative approaches. In this work, we explore a completely different path that employs fixational eye movements. To do so, we

recorded the eye movements of 36 naive subjects while performing standard visual tasks while wearing different optical lenses. Segmenting out their fixational eye movements (i.e., movements during fixations), and obtaining also the participants' visual acuity using a standard Snellen test, we first show that fixation properties correlate well with visual acuity, supporting and complementing earlier findings to this effect. We then show that fixational eye movement patterns collected during different visual tasks can predict visual acuity with even basic machine learning methods. Finally, we show how the visual system adjusts fixational eye movements to visual acuity very quickly, within seconds. Taken together, these findings highlight not only the utility of fixational eye movements as a biomarker for visual acuity but also their clinical applicability.

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Synthetic vision displays

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Advanced visual display technologies have become ubiquitous in the shape of smartphones and gaming consoles. They display virtual objects which are typically unrelated to the world of the user (e. g. a video game) or indirectly related to it (e. g. maps and navigation tools). See-through technologies superimpose virtual objects onto the real world. We claim that this world of virtual realities enters a new stage by replacing the images available to the naked eye with a camera-based image. Other than in classical augmented reality, such as with head-up displays in cars or with head-mounted see-through displays, novel displays no longer provide a direct view of the world. Instead, as sole visual contact with the world, they use a video image, which is contrast-enhanced, augmented, or otherwise manipulated. We call them synthetic displays. Do such modern displays deserve to be called extended reality displays, or are they rather reality-replacement displays? Synthetic displays have mostly been researched for airplane cockpit implementation. We discuss such view-altering synthetic displays in general, and camera-monitor systems (CMS) designed to replace rear-view mirrors as a special instance of a novel synthetic display in the automotive domain. In a standard CMS, a camera feed is presented on a monitor, but could also be integrated into the windshield of the car. More importantly, the camera feed can undergo alterations, augmentations, or condensations before being displayed. We also present an experiment examining the impact of information reduction on a time-to-contact (TTC) estimation task. In this experiment, observers judged the TTC of approaching cars based on the synthetic display of a futuristic CMS. Promisingly, TTC estimations were unaffected by information reduction. Thus, synthetic displays can be useful in some contexts; can they also be harmful?
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Stimulus distributions influence applicability of different adaptive approaches for categorization experiments

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Finding decision boundaries for binary categorization tasks in high-dimensional spaces can be challenging. To sample the high-dimensional space exhaustively, one would need an infeasible number of trials. Adaptive methods address this problem. They use the information from previous stimulus-response pairs to find a region of interest to sample from. In Machine Learning a common adaptive method is uncertainty sampling. Here, the label for samples far from the decision boundary is assumed to be already clear, since it is defined by previously seen stimulus-response pairs that are closer to the decision boundary. For samples that are closer to the decision boundary than anything sampled so far, the label is, however, uncertain. Therefore, samples close to the decision boundary provide more information about the decision boundary. We adapt this idea to adaptive behavioral experiments, but show that it is not applicable in some typical settings. We simulate different experimental settings in 2 dimensions. When the two category distributions do not overlap there are only few stimuli close to the decision boundary that are selected repeatedly. In this case the decision boundary does not get better over time and can even be biased depending on the exact locations of the few close stimuli. The distance to the decision boundary alone, therefore, is not an adequate measure of a stimulus' informativeness. Therefore, we propose a method to select the next stimulus based on reducing the entropy over multidimensional psychometric function parameters in the next step. We show that this is better in selecting stimuli, especially in the case where the two category distributions are far away from each other.
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Handling visual distractors via negative filters: insights from serial dependence

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In the continuous flow of visual input, certain elements can be less relevant or even distracting. While attention employs various strategies to mitigate or suppress distractors, it remains unclear how these stimuli are processed and whether they leave tangible traces in our perceptual experience. To address this, we leveraged serial dependence to investigate the impact of visual distractors on perceptual judgments. Participants were asked to reproduce the orientation of a series of Gabor stimuli while intermittently performing a visual discrimination task, where oriented Gabors acted as distractors. Our findings revealed evident attentional capture by the distractors, indicating their interference with the discrimination task. Crucially, we observed that distractors also interfered with serial dependence in the orientation reproduction task, leaving a subtle repulsive effect. This effect caused current perceptual judgments to deviate from previous stimuli with orientations similar to the distractor. We propose that our approach can open promising avenues to understand the inhibitory mechanisms and temporal dynamics by which the brain handles distraction suppression.

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High levels of awareness for reflexive and deliberate eye movements

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Saccades are one of our most frequent actions, and therefore provide a useful test bed for assessing sensorimotor awareness. Here, we used pro- and anti-saccade tasks to explore differences in awareness between reflexive and deliberate eye movements, and its contingency on the visual consequences of such visual actions. In each trial, we displayed a fixation dot and two saccade targets (distances: 1, 3, 6, or 10 dva), before one target flashed larger for 40 ms. The color of the fixation dot prompted a saccade either to the flashed (pro-saccade) or the non-flashed target (anti-saccade). To investigate the role of visual consequences, we simultaneously showed a phase-shifting Gabor with high temporal frequency (>60 Hz), either above or below the midline, that was invisible during stable fixation. However, the stimulus could be detected, when slowed down on the retina by a saccade. Across sessions, we systematically varied the informativeness of perceiving that stimulus, which either signaled saccade direction, saccade correctness, or no information. Upon reaching the target, observers reported if they perceived the grating above or below the midline (visual sensitivity) and if they believed that their first saccade went to the correct target (saccade sensitivity). Visual sensitivity was high for both pro- and anti-saccades, especially when stimulus phase shift and saccade directions matched. Observers generated around 30% erroneous pro-saccades when an anti-saccade was instructed, as compared to only around 1% erroneous anti-saccades in pro-saccade trials. Saccade sensitivity was high irrespective of stimulus presence or its informativeness. It increased with target distance and was largely comparable for pro- and anti-saccades—with lower hit and false alarm rates in anti-saccade trials (i.e., for erroneous pro- and correct anti-saccades). Together, our data suggest a robust awareness of even reflexive saccades which increased for larger movements, but did not profit from additional visual consequences.
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Enriching Strabismus Evaluation through Immersive Virtual Reality and Comprehensive Cover Test Protocols

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In strabismus the visual axes of the eyes are misaligned, with negative consequences on binocular vision and depth perception. This disorder affects 3-5 percent of children. In standard clinical practice, the cover test assesses the strabismus angle in fixed conditions, such as a single gaze direction (the primary position) and one single vergence distance, typically near (40 cm) or far (6 m) viewing distance with head fixed in straight-ahead direction. This approach relies on the individual ophthalmologist's expertise and overlooks aspects related to natural conditions like other gaze directions and heading influences. Employing Head-Mounted Displays (HMD) with embedded eye-trackers would allow extending standard procedures to quantify strabismus angle under varying conditions. This technology paves way for a systematic analysis of significant dynamic aspects such as fatigue, timing of covering, and latency (period) before eye recovery movement. Notably, they could provide a deep characterization of behaviour. To this end, we used an HTC Vive Pro Eye to administer an alternating cover test. The procedure requires the subject to fixate on a virtual visual target while each eye view was alternately occluded, allowing for accurate measurement of ocular deviation. We explored the impact of head rotations and different gaze eccentricities on ocular alignment in ten subjects without diagnosed strabismus. We also investigated the potential fatigue induced by prolonged testing. Preliminary results revealed heterogeneous behaviour for different eye-head relative positions, indicating a degree of variability in ocular alignment dynamics. Despite concerns about potential fatigue induced by prolonged testing, measures remained consistent across many trials, suggesting minimal eye fatigue. Summarising, using HMD technology to implement a cover test protocol has the potential to provide valuable insights into strabismus assessment, setting a framework for a deep analysis of ocular alignment dynamics under ecologically realistic conditions.

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How watching yourself interacts with affective priming

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During affective priming, the reaction time to an emotional "target stimulus" following an emotional "prime stimulus" is faster, if prime and target are from the same emotional category, compared to if prime and target are from different categories. Reaction times to a stimulus can also be increased, when the presented task-relevant stimulus contains information about the participants themselves, e.g. their image or name, compared to non-self stimuli ("self-reference effect"). This study investigates the mutual influence of affective priming and a self-reference effect. Participants were presented with prime words, which could have either positive or negative emotional content. Each prime word was followed by a target picture, which either displayed the participants themselves (self condition) or a stranger with roughly similar hair, skin color and age (non-self condition). Participants indicated by key press, whether they perceived the image as positive or negative. 80 participants took part in this exploratory study. We compared median reaction times (Wilcoxon tests) and reaction time variability (Levene tests) of positive and negative prime words separately for the self- and non-self-conditions. We found slower reaction times to non-self pictures in the case of negative compared to positive primes ($p < 0.05$). This relatively weak reaction time effect to non-self pictures comes with a strong reaction time variability effect ($p = 0.01$), indicating a considerably larger

reaction time variability with negative compared to positive priming. No such effects were found in the self-reference condition. The present median reaction time effect for the non-self stimuli replicates previous findings about affective priming. We postulate that a potential increase in reaction times in the case of self-reference stimuli may have compensated the decrease in reaction times due to a negative affective prime. In a follow-up EEG-study, we plan to look for physiological correlates of affective priming and the self-reference effect.
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Neurophysiological correlates of prior exploitation in representational momentum

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When observers have to remember the last position of a moving object before it disappears, their memory tends to be slightly distorted, as they often perceive a displacement in the direction of the previous motion. This perceptual effect is known as 'representational momentum' (RM) and provides crucial evidence of the predictive nature of visual perception. The aim of this study was to delve into the electrophysiological correlates of this effect, which at present are still poorly investigated. The experimental paradigm involved electroencephalographic recording during the presentation of clockwise rotating bars that participants (N=38) had to compare to a probe stimulus. This probe could have the same orientation as the target at the end of the rotation, or be slightly tilted clockwise or counterclockwise. Investigating event-related components, we found that right occipito-parietal areas exhibited early (P1 and N1), but also later (N2) modulations, which encoded not only low-level stimulus features such as stimulus speed and probe orientation but also the degree to which participants were affected by RM. Specifically, when a stronger RM effect is expected, but participants detect the incongruence of the probe, these components display greater amplitudes, suggesting a mismatch-like effect where perceptual experience contrasts prior expectations. Furthermore, we found an increase of the P300 in central electrodes when participants detected the incongruence of the probe orientation, but this effect was not modulated by the strength of RM and thus could possibly reflect a working memory update unrelated to the predictive perception triggered by motion. These results fit within the framework of the predictive brain and suggest that the implicit encoding of prior information acts already upon the initial stages of perceptual processing, while later stages of working memory update seem independent from the strength of perceptual priors.

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Balancing exploration and stabilization: age effects in gaze control during locomotion in a virtual environment

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During locomotion the need for walking safely and exploring the environment must be balanced. With increasing age, the risk and costs of falling get higher. It has been suggested that this drives prioritization of gaze towards the ground in older adults. We assessed age effects on the gaze distribution during locomotion in a virtual environment – in particular whether a search task affects the gaze pattern differently between the age groups. We asked a sample of younger (N=24, M=26.0 years) and older (N=24, M=67.6 years) adults to virtually locomote through a VR hallway twice, either with or without an additional search task for target objects on the walls. Search performance was similar in both age groups (94% and 88% target detection in younger and older adults, respectively). In both conditions, older adults' gaze distribution was shifted more towards the ground in comparison to patterns of younger adults. However, the gaze distribution was subject to a significant interaction between the factors age group and task: Younger and older adults oriented their gaze less towards the ground when performing the search task, but this task-specific adaptation was more pronounced in older adults. In addition, we observed in both age groups considerable inter-individual variability of the gaze distribution during locomotion without additional task. This variability was substantially reduced during search. Our findings show age-related gaze prioritization towards the ground in a VR environment, corroborating prioritization of gait-related gaze in older adults. This age effect is strongly attenuated when a task that calls gaze guidance to regions at eye level is introduced. We conclude that older adults are able to flexibly adapt their gaze behavior to task demands, but this might critically interfere with giving priority to safety, e.g., to maintaining a stable gait.
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Investigating memory and learning effects on contextual feedback signals in layers of early visual cortex

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In rodents, the anatomical location for the influence of memory structures on cortical processing is in sensory cortical layer 1. Such a signature of memory-dependent learning has not yet been investigated in layers of human sensory cortex. In our previous human fMRI studies, we have used a homogeneous white occluder over natural scene images to isolate the role of feedback signals to layers of primary visual cortex V1. Here, we investigated how contextual feedback processing in V1 depends on our ability to memorise the image based on prior learning. We acquired 7T fMRI data while showing participants visual scenes belonging to two categories (city and office, each image only showed once). We occluded the lower right quadrant of these images to isolate the role of feedback from surrounding contextual information in V1. Importantly, to investigate the role of memory, we included a training session before scanning during which the participants saw a subset of the images once, and another subset 7 times. This resulted in 3 groups of images during scanning: unfamiliar (novel presentation), familiar (already seen once) and very familiar (already seen 7 times). Behavioural analyses revealed increasing accuracy in image recognition with higher presentation frequencies. In our fMRI data, we were able to decode image familiarity (very familiar vs familiar/unfamiliar), but not image category (city vs office) in occluded V1. Our preliminary results suggest that familiar images are more decodable than novel images, in line with rodent data showing that neuronal responses to occluded images

are strengthened with familiarisation. By contrast, we observed significant decoding for category but less detectable memory modulation in non-occluded V1. Our ongoing analyses will investigate the cortical-layer dependency of our effects in V1.

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Size constancy counteracts subjective image quality drop driven by vergence-accommodation conflict in stereoscopic displays

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Purpose: Rendering an object at different vergence distances in stereoscopic displays often results in vergence-accommodation conflicts – a mismatch between vergence (depth) and accommodation (focal) cues. In addition, vergence is one of the strongest binocular cues for size constancy and it greatly impacts subjective perception of size. Vergence-accommodation conflicts are known to reduce subjective image quality; however, it is not known if size constancy influences this effect. The aim of this study was to evaluate the interplay between size constancy, vergence-accommodation conflicts, and subjective image quality in stereoscopic displays. Methods: Nineteen participants (mean 28.9 ± 5.7 SD) with normal vision participated in the study. The task was to compare the subjective image quality of a virtual newspaper rendered stereoscopically at the same angular size with or without vergence-accommodation conflicts. The vergence-accommodation conflicts were induced either by changing only the vergence distance of the newspaper (vergence condition) or only the focal distance of the displays (accommodation condition). Thus, in the vergence condition, we induced both vergence-accommodation conflict and vergence-driven size constancy, and in the accommodation condition, we induced only vergence-accommodation conflict. We compared the data between the two conditions, to evaluate the interplay between size constancy, vergence-accommodation conflict, and subjective image quality. The data were collected using a high-resolution, varifocal virtual reality headset ('Varifocal Butterscotch'), that allowed to vary vergence and focal distance independently between 0.7D and 3.0D. Results: In the accommodation condition, we saw the expected decrease in subjective image quality driven by vergence-accommodation conflict. In the vergence condition, the impact of vergence-accommodation conflict was exaggerated at shorter vergence distances and diminished at longer vergence distances. We speculate that this effect was mediated by the size constancy-driven perceptual minification and magnification, respectively. Our study provides evidence that size constancy may impact perceptual image quality.

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Visual acuity and stereopsis screening application: pilot validation on an elderly age group

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Fall-related fractures pose a significant threat to the elderly population, often resulting in increased morbidity and mortality. Visual impairment, alongside other risk factors such as age and gender, plays a crucial role in falls. Early detection of visual deficits and adequate intervention are vital for mitigating these risks, highlighting the need for cost-effective and accessible screening tools. To address this, we conducted a pilot validation study to assess the efficacy of a novel vision screening application, EuvisionTab, designed for bedside assessment. Our study enrolled 132 elderly participants (mean age: 72.68 years) from General Practitioner's offices. We compared visual acuity and stereovision measurements obtained via EuvisionTab with established gold standard methods. Binocular visual acuity was assessed using ETDRS chart and EuvisionTab, while stereovision was evaluated with TNO and EuvisionTab stereotests (static and dynamic). The EuvisionTab stereotests employed a pass/fail criterion of 8/6 correct responses out of 10 presented optotypes for static/dynamic stimuli, respectively, while for TNO a disparity threshold of 240' was used. Visual acuity measurements (n=54) demonstrated no significant difference between EuvisionTab and ETDRS-chart (paired-sample T-test; p=0.1401). However, Bland-Altman analysis revealed a positive proportional bias (p=0.0124), indicating slightly poorer VA readings with ETDRS-chart at poorer acuity levels. Despite this, the overall agreement between the methods remained acceptable. Comparing static and dynamic EuvisionTab with TNO stereotest (n=102), McNemar tests showed no significant difference in performance between static EuvisionTab and TNO (p=0.1338). However, dynamic EuvisionTab exhibited a notable disparity (p=0.0009), indicating a higher incidence of reduced stereovision than TNO. Our findings suggest that EuvisionTab is a promising vision screening tool for the elderly. While it aligns well with gold standard methods for visual acuity and stereovision assessment, discrepancies in dynamic stereovision necessitate further investigation to enhance fall prevention strategies. Further refinement and validation of EuvisionTab could significantly benefit elderly fall prevention efforts.
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Hyperspectral Compression through Reflectance-Based Cone-Excitation Ratios

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Hyperspectral images allow for precise scene renderings under different illuminant spectra. However, hyperspectral imaging is expensive and technically demanding. At the same time, the range of naturally occurring reflectance spectra is limited to an extent that there are barely any metamer mismatches. Under natural conditions, cone excitation ratios across the scene remain stable under illuminant changes. We exploited stable cone-excitation ratios as a new approach to compress hyperspectral images in a perceptually meaningful way. We developed generic, reflectance-based cone-excitation ratios (rCERs), assuming an equal-energy white illuminant and relating all surfaces to a (virtual) white reflectance standard. This allowed us to approximate each pixel in any hyperspectral image as a well-defined rCER independent of the illuminant. We assessed how well rCERs approximated hyperspectral renderings. We rendered hyperspectral images of variegated scenes using both our approximate method and original spectral information, under broadband naturalistic

illuminants in 8 hue directions. In a 4-Alternative-Forced-Choice task, participants were asked to identify the odd image out among three identical spectral renderings and one approximate rendering. Our results indicated that observers could distinguish the approximate from the original spectral renderings above chance level under all illumination colours. Although many colours did not seem to change in a visible way, there was always at least one colour that visibly changed and allowed observers to detect the odd one out above chance level. Discriminability also varied across illumination colours, being highest for green and lowest for blue-red, and across scenes, being highest for images featuring single objects with homogeneous colours. These results imply that rCERs cannot replace spectral renderings for some surface and illuminant colours. Our findings can be used to develop solutions that include representations of those colours.
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Representations of cue directionality and agent mental states in gaze following

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Gaze following is an essential social behavior, but the processes behind it remain poorly understood. A significant unresolved issue revolves around the question of whether gaze following reflects the computation of eye gaze direction or mental state of the gazer. We addressed this question using a variant of the gaze cueing task in which we manipulated the perceived intentionality of eye gaze, eye gaze directionality, and perceived gazer's mental content. Participants viewed videos of a gazer looking left or right, making either intentional or instructed gaze shifts with observers unaware of this distinction. The response targets, which occurred on the gazed-at or non-gazed-at locations, invoked either a combined or a dissociated mental representation, such that either both parties perceived the same target (i.e., M) or a different target (i.e., E vs. 3). We examined the data by analyzing the performance difference between egocentric and altercentric visual perspective match. A spatial mismatch in visual perspective produced the largest detriment in performance, such that participants were the slowest to respond when the spatial frame of gaze direction mismatched between the gazer and the observer. A mental mismatch also produced a performance detriment, which was smaller in magnitude. The results did not vary with intentionality of the gaze shift. These data show that gaze following induces spontaneous perspective taking and the computation of both cue directionality and the gazer's mental content.

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Sensitivity to oriented-content of the face is shaped by the nature of the horizontal cues

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The tolerant recognition of individual identity is a core and challenging function of the human visual system. Past evidence shows that humans are particularly sensitive to horizontal cues when identifying faces. It is generally assumed that face identification is horizontally-tuned because most of the face-image energy (i.e., contrast) is contained in this orientation range, due to the horizontal structure of the main features and their configuration (e.g., eyes, brows, mouth). Here I present three studies aimed at further characterizing the orientation tuning of face identification. A first study, testing the identification of orientation-filtered familiar faces presented upright or with a left/right tilt of 45° and 90° indicates that horizontal tuning is face- and not observer-centred. A second study aimed at characterizing the nature of the information contained in the horizontal range of the face-stimulus. Past research has proposed the existence of two main sources of face-identity information: feature configuration and surface properties, disrupted by inversion and contrast negation, respectively. Participants performed an identity recognition task using orientation-filtered (0° to 150°, 30° steps) familiar faces presented upright, inverted, or negated. We modelled the inversion and negation effects across orientation using a Bayesian Gaussian mixed model. The inversion and negation effects peaked in the horizontal range and showed strikingly similar orientation tuning profiles. This indicates that the horizontal tuning of face identification is due to this range facilitating the access to configuration as well as to surface cues to identity. In a third study, we show that the rich configuration and surface identity cues conveyed by the horizontal range are also the most stable across viewpoints, which optimally supports viewpoint-tolerant identity recognition. Altogether, these results indicate that the horizontal content of the face stimulus provides a privileged access to the configural and surface cues and optimally drive view-tolerant identity recognition.

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Automatic processing of variance in multiple facial expressions: Evidence from visual mismatch negativity

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The variance of multiple facial expressions can be extracted efficiently. However, it remains unresolved whether processing emotional variance is automatic and whether it is impacted by types of emotions. In the current study, we employed a passive oddball paradigm and recorded event-related potentials while participants did an attentional demanding task to detect the changes in the central fixation. A set of four faces was presented in the periphery, either showing low or high emotional variance, which was manipulated by changing the distance of emotional units among faces. The two variance conditions had matched mean emotions and were shown with a probability of 20% (deviant) and 80% (standard) respectively in the sequence, or vice versa. In Experiment 1, the face set consisted of two angry and two happy faces. In Experiment 2, all four faces were angry or happy. The results showed that in Experiment 1, low emotional variance did not elicit visual mismatch negativity (vMMN), while high emotional variance elicited both early (110-140 ms) and late (320-420 ms) vMMN. In Experiment 2, under the low variance condition, angry faces elicited vMMN in the time window of 320-420 ms, while happy faces did not. In contrast, under the high variance condition, both angry and happy faces elicited visual mismatch responses at around 320-420 ms. Taken together, we found that the variance of multiple unattended facial expressions can be perceived

automatically. Moreover, there is an advantage in the processing of higher emotional variance and a negative emotional bias in variance perception.

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The consequences of preparing for informative or distracting stimuli

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How do individuals prepare for impending distractors? It has been recently suggested that not only observers do not inhibit distractors before their appearance, but they are rather more alert at those moments. Interestingly, a similar effect emerges when observers anticipated task-relevant, informative stimuli, supporting a mandatory "attend-all" mechanism. However, thus far, the preparation effect was only demonstrated in speeded dot-probe tasks, and it is yet to be determined whether preparing for distractors merely facilitates motor preparation or extend to other outcomes, such as modifying early perceptual processes. To broaden the scope, we replaced the dot-probe task with a four-letter memory encoding task. In two experiments, participants performed a change detection task that included three conditions. In the No-display condition, nothing but a blank screen appeared during the retention phase. In the Informative-display condition, the initial memory display reappeared during retention, offering participants the opportunity to enhance their performance. Conversely, in the Distractors-display condition, a confusing display was displayed, and participants were advised to ignore it as it might hinder their performance. To probe attention, in 25% of the trials four letters were displayed at the exact moment in which the Informative/Distractors display was expected, and participants were required to report as many letters as possible. As anticipated, the performance in the change-detection task was best at the Informative- and worst at the Distractors-display condition. Regarding the letters' memory, it was enhanced when letters appeared during the anticipation of informative stimuli. Importantly, memory was also heightened, albeit to a lesser extent, when observers expected distracting stimuli to appear. These findings suggest that the preparation effect extends beyond motor preparation, influencing perceptual processes at an early stage. This indicates that the preparation effect has perceptual consequences, and that it is more flexible than previously thought.

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Is saccadic suppression related to metacontrast masking?

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To explore our visual world, we make rapid saccadic eye movements with typical speeds of several hundred degrees per second. The fast movements cause the image to sweep across the retina, leading to a blur or smear. Interestingly, observers typically remain unaware of the retinal motion and smear while making saccades—this is referred to as saccadic suppression. One prominent hypothesis to explain saccadic suppression posits that the input during saccades is masked by the stationary pre- and/or post-saccadic stimuli arising from fixations preceding and following saccades. This hypothesis predicts that a similar masking phenomenon should occur in simulated saccades, where the visual stimulus mimicks the retinal input around a saccade while the observer fixates. We have recently confirmed this prediction using a high-frequency display, finding that two clear and static images surrounding saccade-like motion mask the resulting motion and smear. Moreover, it has been suggested that saccadic masking is closely related to metacontrast because the clear images partly surround the saccadic smear. We studied saccadic and metacontrast masking in saccadic suppression using simulated saccades in two experiments in which we varied the interstimulus interval between the masks and the moving stimulus, and searched for the nonmonotonic dependence of masking on this interval, the U-shaped function characteristic of metacontrast. In one experiment we showed that two moving shapes can be discriminated without a mask, but this discrimination becomes more and more difficult as the duration of the mask increases. In a second experiment, we showed that the shape of the masks replaces the shape of the moving target as mask duration grows. In both experiments, the masking decreases as ISI or SOA increases. However, we found no trace of a non-monotonic U-shaped pattern as a function of SOA, indicating that metacontrast masking is not closely related to saccadic suppression.

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Structural constraints in sparse predictive-coding networks reconcile Bayesian and 'anti-Bayesian' effects in human orientation perception

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Biases in perception are typically thought to reflect the influence of prior expectations on sensory processing. Natural scenes are dominated by horizontal and vertical local orientations, and it has therefore been argued that the visual system implements a prior biasing orientation perception towards cardinal orientations. The existing evidence, however, suggests that this view may be too simplistic. Psychophysical studies report perceived orientation to be biased away from cardinal orientations. Neuroimaging studies, however, suggest that neural representations are biased towards cardinal orientations. Here, we reconcile these findings using neural-network modelling combined with psychophysical testing. We implemented a sparse predictive-coding network as a biologically-plausible framework for perception and learning in the visual system. Following training on natural scenes, orientation processing was tested with orientated gratings of varying contrast. The network's perceived orientations were decoded from unit activations using a standard population vector-average approach. In line with previous work, the network developed orientation-tuned receptive fields in a V1-like layer. Anisotropy emerged spontaneously, with greater preponderance of units tuned to cardinal than to oblique orientations. This non-homogeneity acted as a structural constraint, reproducing the oblique effect characteristic of human vision: a sensitivity advantage for cardinal relative to oblique orientation. Moreover, the non-homogeneity generated attractive biases in neural representations towards cardinal orientations. Importantly, due to lateral-inhibition, these biases increased with stimulus contrast. Consequently, when tested in a 2-interval-forced-choice setup characteristic of psychophysical experiments, with a low-contrast test

stimulus and a high-contrast reference, the network reproduced the pattern of apparent repulsive biases seen in human observers. Overall, these findings demonstrate that, when optimised for natural images, sparse predictive-coding networks spontaneously learn structural constraints leading to counter-intuitive effects in tests with artificial stimuli in line with those observed in humans. These findings are able to reconcile apparent contradictions in human psychophysics and visual neuroscience.
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Creating High-Fidelity Human Avatars for Behaviour and Cognition Research

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In the field of face perception research, two methodological methods dominate: laboratory experiments and field studies. While laboratory experiments have provided some fundamental insight into various aspects of face perception, their tightly controlled nature means they lack ecological validity. In contrast, research conducted in real-world settings are more generalisable to everyday scenarios, but are missing the control necessary to isolate specific processes. Thus, a core issue in behaviour and cognition research is how to balance experimental control with real-world relevance. One solution to this problem is virtual reality, which allows users to experience highly immersive virtual environments that reflect the real world. In addition, researchers can still control variables of interest, allowing cause-and-effect to be established. Here, we detail a method to create avatars for use in such virtual environments. These avatars are based on the identities of real people and are rigged for full facial movement, encompassing eye-gaze, speech, and emotional expression. We provide a demonstration of the fidelity of these avatars to illustrate how these dimensions can be applied in a broad range of psychological experiments.
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Foraging through emotions: the role of emotional valence in target selection during visual foraging

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In multi-target visual foraging, observers are required to search for several instances of several target types. A critical question concerns the factors driving target selection. Previous work suggests that target selection is achieved through the competition between different factors (e.g., proximity, priming) that orient attention towards one of the possible targets. However, this research has mainly involved simple stimuli such as colored dots. The real-world visual environment is mostly composed of complex stimuli that often convey emotional content, which may contribute to target selection. In single-target visual search, emotional stimuli (e.g., pictures, faces) with positive or negative valence have been shown to capture attention over neutral stimuli. In the current study, we designed a visual-foraging task involving real-world photographs eliciting negative, neutral or positive emotions as stimuli. 72 observers had to complete three foraging tasks corresponding to three emotional-valence conditions: in the positive, neutral, and negative blocks, participants had to select 24 images eliciting respectively positive, neutral and negative emotion, among 24 neutral distractors. All participants completed the three blocks in a within-subject design. In each block, there were always two target types and two distractor types, and the task was to select all the targets as fast as possible, while ignoring the distractors. We measured observers' foraging strategy (i.e., selection order, number of switches between target types) and performance (i.e., selection times, number of distractor selections). Additionally, we assessed participants' trait-anxiety to examine how it could modulate the influence of emotional valence on foraging behavior. The results reveal that emotional valence influences both foraging strategy and performance, and suggest that these effects are modulated by participants' trait-anxiety levels. These findings importantly show that high-level factors, such as emotional valence, contribute to target selection during foraging, and highlight the need for using ecologically-valid stimuli in visual-foraging research.

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Signalling of collision threats by predictive suppression of local optical flow from moving observers

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Visual detection of objects that approach an immobile observer is straightforward. When the observer itself moves, however, "background movement" (BM) occurs. Then, distinguishing between objects that eventually miss the observer (due to BM) from true collision threats turns into a difficult computational problem. Many organisms have dedicated neurons which reliably signal object approaches irrespective of BM. Understanding the underlying computations is highly relevant for applications such as car driving or robotics. Most of the biologically-inspired computational approaches rely on the integration of temporal contrast. The such generated signal encodes an object's angular velocity. However, BM typically interferes with a reliable interpretation of this signal. Here I propose a new computational model for signaling object approaches. It is based on locally suppressing predictable features of the optical flow field. In this way the model learns the spatio-temporal structure of the environment through which an observer moves, and encodes collisions as unpredictable events. In contrast to comparable approaches which use optical flow, my model (i) is not based on binocular information (e.g. flow field balance); (ii) does not rely on global properties such as flow field divergence; (iii) does not require an active vision strategy for estimating distances (e.g. via motion parallax). Rather, it is monocular, acts locally, and relies on passive sensing. My model appears to be consistent with the computations of insects' visual circuits. Formally, the biological credibility is further strengthened by the fact that my model describes the dynamics of neurons. Model performance was systematically evaluated with artificial and real-world video footage. Overall, my model is able to signal collisions in challenging environments. It performs at least on

par with several state-of-the-art published models and computer vision algorithms, respectively, which use different information than optical flow.
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Comparing Gaze-Mediated Orienting of Attention Between Schematic and Real Human Faces

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In social interactions, our gaze naturally follows the direction in which others look. Yet, in contemporary societies, we frequently encounter a variety of facial images, from simple icons to depictions of imaginary characters, commonly seen in ads and on digital platforms. This research contrasted how eye-gaze from stylized and actual faces affects our visual attention. We conducted three studies involving 400 participants in total, where we measured either manual (in the first two experiments) or eye-movement (in the third experiment) responses. In these experiments, participants were exposed to both stylized and real faces, either in separate blocks or mixed within the same block. The mixed condition was designed to explore potential differences in attention response to stylized versus real faces in settings that mimic everyday situations filled with diverse stimuli. Across all studies, a consistent gaze-cued attentional shift was observed, regardless of whether the faces were stylized or real, or whether they were presented mixed or separately. These findings indicate that our social attention mechanisms might respond similarly to both types of facial cues, opening up fascinating prospects for applying such gaze cues in practical scenarios, despite their low naturalistic resemblance.
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High-frequency alpha activity involved in the top-down control of internal representations during working memory maintenance

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Background: Short-term memory (STM) sustains information temporarily, while working memory (WM) is defined as goal-directed manipulation of information in STM. The neural background of memory-related processes has been widely studied but several previous studies of visual WM maintenance have operationalized it in a way that is more consistent with STM, i.e., maintenance of information over a short delay, with no additional processing demands. These studies found both local and interareal oscillatory changes in several frequency ranges, e.g., theta (4-8 Hz) and alpha (8-12) during maintenance. Objectives: Our objective was to identify local and interareal oscillatory mechanisms dissociating WM and STM, in a task where participants had to either mentally manipulate the maintained information (WM) or not (STM). We hypothesized that increased top-down modulation in the WM condition would be associated with increased theta and alpha activity during maintenance. Methods: We recorded brain activity with simultaneous MEG-EEG during a retro-cued delayed- match-to-sample memory task from 43 healthy young adults (ongoing). After the presentation of S1 which could include shapes and/or gratings, a retro-cue indicated whether all probe stimuli (shapes and gratings; STM condition) or only stimuli belonging to one category (shapes or gratings) had to be maintained during a delay period, while non-cued stimuli needed to be inhibited (WM condition). Results: Source localized oscillatory power in the high-frequency alpha (10-14 Hz) band in parieto- occipital regions was increased during the maintenance (post-retrocue) period for WM compared to STM trials, while prefrontal theta power was decreased. Analyses of interareal synchrony revealed hubs differentiating WM and STM trials in similar regions and frequency ranges, most prominently in alpha. Discussion: Our results suggest that high-alpha band oscillations reflect top-down selective attention acting on internal mental representations during maintenance, while frontal theta is linked to increased resource allocation in conditions with higher mental load.
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Generalized energy operators for the analysis of local image structure

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There is convincing evidence of energy mechanisms in biological vision, involving the combined responses of odd and even symmetric linear filters. These filters can be modelled as directional derivative operators, of first and second order, respectively. In contrast, computer vision systems are typically based on the image gradient alone, without the use of higher derivatives. This work explores the relationship between these alternative representations. Biological energy models are motivated by the characteristics of complex cells, including their phase-invariant response to periodic gratings. Existing approaches, based on squaring the outputs of Gabor or Gaussian derivative filters, are somewhat complicated by the need to impose zero-DC and quadrature phase constraints. An alternative approach is outlined here, based on scale-normalized image derivatives. It is shown that the sum of the squared first and second order derivatives, appropriately normalized, gives an edge response that is invariant to small translations. For periodic structures, it is shown that a more general combination, involving the third derivative, gives complete phase invariance. These models are exact, but require the use of higher-order derivatives, which is consistent with biological data. Furthermore, the edge and grating operators are special cases of a general formulation: the linear combination of all pairwise products of normalized derivatives, up to a given order. The unknown coefficients in such a combination can be determined in relation to real image data, for a given task. Interpretable and biologically plausible energy models can be obtained in this way, by L1-regularized regression. Furthermore, the corresponding optimization problem can be solved exactly, using convex programming methods. For example, it is shown that the image gradient, at a given location, can be estimated from the generalized energy at nearby locations. This finding is discussed in relation to spatial sampling constraints, which differ between biological and computer vision systems.

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Set size and scene background affects individual object and ensemble perception in naturalistic scenes

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Individual object perception involves the individuation and identification of single objects, whereas ensemble perception involves rapidly assessing the average information of a group of objects. Previous studies in this domain primarily used simplistic, uniform backgrounds, making it difficult to assess the effects of scene context on object perception. To move towards real-world settings, we investigated both individual object and ensemble perception in the context of naturalistic scenes. In two experiments, participants had to either remember individual object positions or the average position of all presented target objects. They viewed multiple objects embedded in a kitchen scene on a computer screen, and clicked with a mouse on the remembered single object's or group average position. In both experiments, encoding time was manipulated, varying from 50 ms to 3200 ms. Additionally, the number of presented objects (3, 6, or 10) was varied in experiment 1, and the scene the objects were presented in (naturalistic or textured background) in experiment 2. In both experiments we found an increase in locating accuracy with longer encoding time. However, while individual perception benefited from longer encoding times, ensemble perception was most accurate at about 800 ms. Set size also resulted in different effects on individual and ensemble perception, with increasing locating accuracy in individual perception with decreasing set size and lower locating accuracy in ensemble perception for a small set size. Notably, in experiment 2, scene impact on perception was dependent on encoding time, with the textured background showing a stronger benefit for ensemble perception at short encoding times and no effect of the scene on individual perception. Using naturalistic scenes and stimuli, we show that individual object and ensemble perception are differentially modulated for mid- to high-level factors, such as set size and scene context.
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Characterizing Surround Suppression with Dynamic Natural Scenes

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When a drifting center grating is presented along with an annular grating, perceptual sensitivity decreases compared to when it is presented alone. This suppression effect decreases when the center and annular gratings move in opposite directions. Here, we extend the understanding of surround suppression by investigating the phenomenon in the context of dynamic natural scenes. We presented panoramic scene videos created by moving a static panorama behind a circular occluder. These videos featured natural scenes from two superordinate and two basic-level categories—indoor (e.g., restaurants, museums) and outdoor (e.g., parks, residential areas)—with two exemplars per basic-level category. The central videos were presented either alone or with a surrounding video. Importantly, the relationship between the central and surrounding videos varied, including identical exemplars, different exemplars of the same basic level category, and different identities of the same or different superordinate categories. Participants reported the superordinate categories of both the central and surrounding videos, encouraging them to attend both center and surround. In a baseline condition, the central image was presented alone, and participants reported its category. In each trial, the Michelson contrast of the images was adjusted using an adaptive 1-up, 3-down staircase procedure based on the participants' judgments regarding the central image. Our results showed that surround suppression decreases as the categorical distinction between the center and surround images increases. The strongest suppression occurred with identical central and surrounding videos, while the weakest suppression was observed with videos from entirely different categories. Moreover, surround suppression was decreased when the central and surrounding videos moved in opposite directions. Together, these results reveal that surround suppression is observed for natural scenes, with homogeneity in scene content driving the strength of the effect.
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Vigilant and Prepared: Working Memory-Driven Attentional Capture by Task-Irrelevant Threat Is Contingent Upon Action Preparation

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Stimuli which signal potential threat capture our attention, even when they aren't currently relevant and disrupt our current goals. It has, however, not been determined whether this interference from threat could also partly be caused by a background threat-detection goal active in visual working memory (VWM). To test this, across 5 within-subjects experiments (total N = 119; 4 pre-registered), a visual search task with task-irrelevant affective flankers (i.e., positive kittens, threat-related spiders) was combined with a secondary VWM change detection task. It was expected that maintaining an unrelated positive kitten or threat-related spider image in VWM would cause elevated interference from the peripheral affective flankers when they matched the contents of VWM, relative to when they mismatched. Unexpectedly, VWM matching flankers did not cause slower or less accurate visual search relative to VWM mismatching flankers (Experiment 1), even when they were salient relative to the target array (Experiment 2), and when contrasted against a condition with the change detection task removed to control for potential confounds (Experiment 3). This is despite cumulative evidence across the experiments that the threat-related flanker caused interference independent of the contents of VWM, relative to a baseline neutral flanker condition (i.e., birds). When, however, responding to the VWM change detection task was prioritised, either due to an unpredictable VWM/visual search task order (Experiment 4) or by facilitating action preparation to the VWM task (Experiment 5), VWM-matching threat-related flankers caused greater search interference. This pattern was only observed for threat-related flankers, with

positive flankers failing to interfere with visual search across all conditions. The current study provides evidence for distinct goal-driven and value-driven attentional capture by threat; and suggests that a background goal-driven mechanism may operate depending on varying states of action preparation, rather than general task-relevance amplifying affective perceptual inputs.

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Necker cube's dominant interpretation can be explained by a lower-is-closer perceptual bias

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The perceptually alternating Necker cube has fascinated people and science for almost two centuries. The fact that one perceptual 3D interpretation of the cube is dominant has recently been suggested to stem from typical visual experience of seeing objects from above. Here we illustrate that even without 3D information a bias of judging the lower square as closer seems to remain. We propose that the dominant interpretation of the Necker cube stems from a newly discovered "lower is closer" perceptual bias we report here (n=190) where things in lower visual space appear closer to the eyes than those in upper visual space even when they are equidistant. In fact, in the equidistant condition, when participants were able to report "equidistant" (in a 3AFC paradigm), 55% of the time they reported "lower closer" and only 11% of the time "upper closer", a 5-fold "lower is closer" perceptual bias that was highly significant ($p<<0.0001$). Together these suggest that the lower-is-closer perceptual bias, which may develop following unbalanced visual input statistics, shapes our internal representations and can influence even very basic perceptual experiences.

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Temporal (Un)certainty in Visual Search

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Visual search clearly benefits from knowing what to look for, and was also found to be affected by stimulus timing. Nonetheless, it is unclear how much of this impact is attributable to temporal (un)certainty, and especially how distractor suppression is affected by it. Considering temporal positions as feature-like information, we examine these influences by varying temporal certainty of visual stimuli. We conduct a conjunction search experiment, using two vertical and two horizontal colored bars. In the positive condition, participants search for a blue vertical bar appearing at one of four possible positions, and report the position of a gap in a surrounding circle. In the negative condition, the blue vertical bar is used as a to-be-suppressed distractor, and participants report the gap position of the circle surrounding the non-blue vertical bar. To assess the processing of the to-be-searched or to-be-suppressed color, the search display is preceded by a cueing display, in which a blue dot appears at one of the four possible positions. Proactive processing of the cue is expected to result in shorter (positive condition; due to facilitation) or longer (negative condition; due to suppression) reaction times in trials in which cue and target are presented at the same position compared to different-position trials. To evaluate the impact of temporal (un)certainty, we implement two different types of trial blocks; with certain (100 ms or 200 ms) or uncertain (mixed) cue-target intervals. Temporal certainty is hypothesized to result in stronger cueing effects (i.e., facilitation or suppression, depending on condition) of same-position vs. different-position cues compared to temporally uncertain trial blocks. Results are discussed in light of current theories and constitute significance for central aspects of everyday life, as they reveal the impact of temporal (un)certainty on visual search and attention control.

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The neural dynamics of objects occluded by illusory contours

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To effectively operate in an unpredictable and fast-changing environment, we need to process visual input very quickly. Fast and accurate object recognition in natural environments depends on both robust feedforward processing and recurrent connections in the visual hierarchy. The latter is particularly crucial in the case of recognising ambiguous stimuli, where visual input alone cannot give rise to accurate recognition. These recurrent connections complement feedforward information and occur at different points in time. It is, therefore, important to consider the temporal dynamics of feedforward and recurrent processes in the study of object recognition. Illusory contours and occlusion are two types of ambiguous objects that rely on recurrence to be perceived, which we used here to study how their recurrent processing interacts, to provide information about the role and time course of recurrence in the context of object recognition. We used images of natural objects (e.g., cows, socks, crabs) occluded by valid and invalid Kanizsa illusions, and recorded both behavioural categorisation responses and time-series electroencephalography. Using neural decoding methods, we found that evoked neural signals contained reliable information about both the presence and shape of the illusion. In addition, results showed high behavioural accuracy and strong neural object coding in both valid and invalid illusory occlusion conditions. Our results highlight the robustness of object representations in ambiguous contexts.

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Retinal and cortical chromatic SSVEPs in normal and anomalous trichromats

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In anomalous trichromacy the spectral sensitivities of the long (L) and medium (M) wavelength sensitive cones overlap to a greater degree than in normal trichromacy. This reduces the red-green colour signals achieved by comparing the activities of inputting L and M

cones compared to those present in normal trichromacy, and consequently impairs red-green colour discrimination. However, it is thought that anomalous trichromats may employ 'postreceptoral compensation' to relatively normalise the range of red-green chromatic contrasts encoded by their visual systems, which may relatively normalise the representation of suprathreshold colour differences and colour appearances. Based on the results of one fMRI study, the locus of postreceptoral compensation is thought to be cortical. We aimed to compare retinal and cortical colour signals between normal and anomalous trichromats measured in a single study to further investigate postreceptoral compensation and its neural locus. We presented normal and anomalous trichromats with stimuli that modulated in chromatic contrast at a precise temporal frequency either along the L/(L+M) axis or the S/(L+M) axis of the MacLeod-Boynton chromaticity diagram. We used a 64-channel electroencephalogram (EEG) system to measure associated steady-state visually evoked potentials (SSVEPs) from the cortex. We repurposed two of the channels as electroretinogram (ERG) electrodes placed below the eyes to simultaneously measure retinal steady-state responses. In analysing our data we are developing procedures to optimise our pre-processing pipeline to maximise signal to noise and isolate retinal signals before testing the effects of colour condition and participant group on retinal and cortical SSVEP amplitudes. Without postreceptoral compensation, ratios of L/(L+M) to S/(L+M) SSVEP amplitudes should be smaller for anomalous trichromats than for normal trichromats. However, if anomalous trichromats compensate for reduced cone-opponent signals in their cortical processing, the ratio difference should be smaller at cortical electrodes than at retinal electrodes.
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Revealing the time-course of mid-level feature representations in scenes using rendered stimuli and ground-truth annotations

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Scene perception is a key function of the human visual brain and follows a hierarchy that starts with the processing of low-level image features, continues with mid-level features and culminates in high-level scene understanding. While the temporal processing of low- and high-level features has been thoroughly investigated, mid-level feature processing is less well understood. To address this gap, we created a stimulus set of images and short videos (300 ms) of naturalistic rendered scenes containing single persons performing different actions. From the 3D rendering software we also obtained the ground-truth annotations for five mid-level features as postulated by theoretical models of object recognition: reflectance, lighting, world normals, scene depth and skeleton position. We also obtained annotations for the low-level feature edges and noted the high-level feature action as reference points. We presented these stimuli to human participants and collected their electroencephalography (EEG) data (N=15 for images, N=20 for videos). To investigate the time course of mid-level feature processing, we applied encoding models and predicted the EEG data from the ground-truth annotations at every time point. We observed that the encoding accuracy of our mid-level feature annotations peaked between ~100 ms and ~250 ms post-stimulus for both images and videos. This time-window sits between the results for the low- and high-level features, suggesting that the postulated mid-level features play a role in the transformation of low-level inputs into high-level semantic information. Additionally, we observed that skeleton position and action peaked earlier in videos than in images, suggesting that movement information in videos aids the processing of biological motion in mid- and high-level features. Overall, using a novel stimulus set with ground truth annotations, we revealed the temporal dynamics of mid-level feature representations in images and videos, providing insight into their place in the hierarchical processing of scene perception.
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A Unified Computational Model for Contextual Effects on Facial Emotional Recognition

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Facial expression are perhaps the most efficient ways to communication emotions, especially during online communication when other bodily cues are not available. Contextual factors such as age, gender, and race have been reported to modulate facial emotion expression and recognition, but there is no unified model available to characterize these effects. We filled this research gap by proposing a computational model consisting of competing emotion detectors selective to distinct emotional categories (e.g. happy, sad, fear, anger). When a face stimulus is present, the responses of emotion detectors follow a bivariate normal distribution in a 2-D space (upper face, lower face). The likelihood ratio between emotion detectors determines the emotional discrimination decisions. We can use the participants' decision boundary to quantify the effects from the contextual factors of interest. We tested our model on the own-racial effects: a face recognition advantage toward one's race. We selected 1 female and 1 male target face from each of the 3 face datasets representing Caucasian (Ekman's POFA), Japanese (AIST), and Taiwanese (Taiwanese Affective Stimuli Corpus) people. In Experiment 1, we composed faces by combining the upper and the lower faces with different morphing levels between happy-sad expression of the same target face. In Experiment 2, we composed anger-fear expressions. Caucasian, Japanese, and Taiwanese Participants were recruited to watch all faces and judge the emotion with a 2-alternative forced choice (happy-sad in Exp 1, anger-fear in Exp 2). Our model successfully captures the richness of the racial effects: instead of a simple own-race advantage, we discovered emotion-dependent interaction with the races of the participants. All 3 cultural groups weighted lower-face information more in discriminating sad-happy, and upper- face information more in discriminating fear-anger faces. Cultural-specific patterns were more profound in fear-anger discrimination, suggesting the nature of emotion-specific contextual effects on facial recognition.
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An in-depth investigation of face perception in developmental prosopagnosia

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Developmental prosopagnosia (DP) is characterised by severe difficulty recognising familiar faces but little is known about the exact stage of the human face processing system where difficulties occur, or whether this is the same in all cases of DP. Adults with DP (n = 20) completed six tasks testing both identity and non-identity aspects of face perception. The test battery was informed by the Bruce and Young model of face processing and designed to systematically tap each stage of face processing. Group and individual level results showed that, overall, upright face perception ability was impaired in the DP group whereas perception of objects (houses) was normal. DPs showed group level face impairments at very early, non-identity, stages of face processing including face detection ($p = .008$) and face gender categorisation ($p = .015$). Importantly, these low-level perceptual impairments were observed in the majority (13/20) of the DP group. A subgroup of DPs showed impairment on ≤ 1 face perception task indicating broadly typical face perception and thus support for the idea of perceptual (affecting face perception and face memory) and mnemonic (affecting face memory only) sub types of DP. A third possible subtype of DP affecting face memory and face identity perception only was tentatively identified; these participants (n = 3) showed typical performance on the five non-identity face perception tasks and impairment only on the Cambridge Face Perception Test (CFPT), a task which tests perception of facial identity. Results clearly show that data from a single face perception task (e.g. CFPT) cannot be taken as evidence of broader face perception ability. In both the DP and control groups, intraclass correlations showed clear intra-individual differences across perceptual tasks. The use of multiple tasks to assess different stages of face perception is recommended.
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Is this the real life? Sense of reality as measured by pupil diameter

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Our perception constructs a representation of the environment, which we often accept as authentically representing the world. This connection is referred to as "reality" and our evaluation of its authenticity is known as the Sense of Reality. Distortions in this Sense of Reality are diagnostic criteria for numerous neuropsychiatric and neurological disorders. In this study, we aim to investigate the pupillometric response when the Sense of Reality is challenged (i.e., when we perceive strange experiences diverging from our typical world experience, consciously or unconsciously). Utilizing a novel virtual reality paradigm, we manipulate visual perception to induce "Virtual Hallucinations" that mimic the phenomenology of hallucinations found in psychedelic, psychotic, and mystical states. By methodologically altering various aspects of visual perception in the virtual environment, we can manipulate participants' experiences and analyze their reactions to these “Virtual Hallucinations” through phenomenological responses, pupillometric, kinematic, interoceptive, and neural signals. We use a two-part study design: first, determining each participant's Just Noticeable Difference (JND) to tailor the intensity of experiences. Employing a staircase procedure for each virtual hallucination, creating a common scale for comparison. With the JND, we can tailor the experience intensity to each participant, ensuring a similar experience for all subjects despite individual perception differences. And second, comparing subjective effects based on individual threshold sensitivity. The two parts of the study were conducted within a 1-10-day period and the duration of each part was approximately 2 hours. Our results, drawn from an exploratory experiment (N=32) and a replication study (N=32) after confirming our behavioral hypotheses, demonstrate that pupillometric measurements during virtual hallucinations can decode participants’ sense of reality. These results suggest that experiences of altered reality, such as those found during hallucinations, may manifest in pupil diameter. This may in turn offer a new implicit measure of the Sense of Reality.

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Effects of light level, material appearance, and virtuality on hand movements

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In four experiments, we investigated if and how visual uncertainty and assumptions about the consequences of actions (e.g., collision with an obstacle) shape motor behaviour. Within each experiment, visual uncertainty was varied using three different photopic and mesopic light levels. Assumptions about the consequences of collisions with obstacles were manipulated using obstacles varying in perceived fragility (low vs high fragility). Between experiments, we varied whether the obstacles were real or virtual objects using a mirror setup. In Experiment 1 (N=22), the obstacles were real objects, in Experiment 2 (N=20), they were virtual objects, and in Experiments 3 (N=20) and 4 (N=20), real and virtual obstacles were presented simultaneously at the same location. In all experiments, participants moved their right hand around an obstacle to pick up an object. For each combination of light level and perceived fragility, participants performed ten trials under full vision while the movements of their thumb and index finger were tracked. Based on previous findings, we hypothesised that lower light levels would result in larger safety margins (i.e., distance between hand and obstacle), but the overall magnitude of the safety margins would be smaller for virtual obstacles than for real obstacles. Regarding perceived fragility, we assumed that safety margins would be larger for the more fragile obstacle but only if it was a real object. Consistent with our expectations, we found in all experiments that safety margins increased with decreasing light level. The magnitude of the safety margins, however, did not differ between real and virtual obstacles. The effect of perceived fragility on safety margins was weaker and less

consistent but was, contrary to our hypothesis, present both for real and virtual obstacles. Overall, in this task, obstacle avoidance and grasping behaviour was very similar in real and virtual environments.
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Onset disambiguation of multistable displays perception relies on accumulation of sensory evidence over time

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Our perception provides us with a single representation of the outside world, so we can act upon it. This goal is not easy to achieve even under ideal conditions, as sensory inputs are intrinsically ambiguous. When an observer faces a noisy stimulus and must make a perceptual decision, our sensory system increases the signal-to-noise ratio of sensory evidence by accumulating it over time. This process is often modeled using drift-diffusion models where evidence is accumulated until it reaches a certain threshold (boundary) for one of the hypotheses, with the speed of accumulation being proportional to the strength of the signal. Here, we demonstrate that the same processes also support automatic perceptual disambiguation when observers are confronted with a bistable kinetic-depth effect display. We measured the time required for one of the directions of rotation to be dominant during 50% of the trials following the stimulus onset. We used five levels of perceptual ambiguity, ranging from fully ambiguous to strongly disambiguated stimuli, and measured whether perceptual dominance was already resolved using a forced-ambiguous switch paradigm at 20, 40, 80, 160, and 320 ms after the stimulus onset. We fitted the data from 20 participants using a Bayesian multilevel model with a logistic function to quantify the speed of evidence accumulation. We report that consistent with the idea of accumulation of the sensory evidence over time, the perceptual dominance was resolved 25 ms later for fully ambiguously stimuli compared to the strongest disambiguation condition (63 ms after the onset versus 88 ms for fully ambiguous). We demonstrate the same behavior in the spiking neural model by Laing and Chow. To summarize, we demonstrate that the process of resolving the onset perception in multistable displays requires the accumulation of sensory evidence over time.

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Are gaze differences between nature and urban images due to environment type or preference?

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It is generally assumed that nature and urban environments place differing demands on visual attention. For example, for the same presentation duration, urban environments have been linked to a greater number of exploratory eye movements, whilst nature scenes evoked fewer and longer fixations (Franěk et al, 2018, Journal Environmental Psychology, 57, 10-16). Here, we wondered whether differences in gaze behaviour might be related to differences in scene preference rather than to differences in environment type per se. Using eye tracking and a simple 2AFC task to indicate preference for simultaneously presented images (nature images N = 16, urban images N = 16; N trials = 496), we explored the role of value-based and attention-based decision making for nature and urban images, thereby testing assumptions of the attentional Drift Diffusion Model (aDDM) by Krajbich and colleagues (2010, Nature Neuroscience, 13(10), 1292-1298). Before and after the 2AFC task with eye tracking, participants (N = 16) were also asked to provide individual liking ratings for each image. Consistent with model predictions, we found that image values (and indeed the absolute differences in liking values between two simultaneously presented images) strongly influenced gaze behaviour and reaction time, an effect independent of environment type. Furthermore, we observed that cumulative fixation time served as a predictor for final choice. These findings highlight no categorical differences in gaze behaviour between nature and urban images, and therefore support general assumptions of the aDDM regarding value and choice across environment type boundaries.

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Temporal recalibration for asynchronous onset and offset of audio-visual stimuli

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When audio and visual stimuli are consistent with a certain constant temporal asynchrony for a few minutes, the perceived asynchrony between the stimuli would be reduced (audio-visual temporal recalibration). In our previous study (VSS2021), we used audio-visual stimuli longer than 200ms for which participants easily distinguished their onset and offset. We found significant temporal recalibration for the onset (offset) after exposure to asynchronous onset (offset) although we found no temporal recalibration for the onset (offset) after exposure to the asynchronous offset (onset). The present study aims to elucidate the mechanism underlying the audio-visual temporal recalibration for the stimuli whose onsets are distinguishable from their offsets. In Experiment 1, we investigated whether the onset-offset channels, which process the onset and offset of stimuli independently, are responsible in temporal recalibration. Participants were exposed 180 times to either of asynchronous onset or offset with a constant temporal lag (±240ms) in the adaptation phase (positive lag means that the audio stimulus followed the visual stimulus), and made temporal order judgments for the offsets in the test phase. We found no temporal recalibration. In Experiment 2, we investigated whether the subjective binding between the onset (offset) of the audio stimulus and the offset (onset) of the visual stimulus are responsible in the audio-visual temporal recalibration. Participants were exposed 120 times to asynchronous onset and offset in the adaptation phase with a constant temporal lag (0ms, ±240ms), and then made temporal order judgments for the onset and offset of the audio-visual stimuli in the test phase. We found significant temporal recalibration only for the -240ms condition in which the audio stimuli overlapped with the visual stimuli. These results suggest that the audio-visual temporal recalibration depends upon subjective binding between the onset and offset of audio-visual stimuli, rather than early independent on-off channel.
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Extraction of facial impression factors using eye-tracking and Grad-CAM

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Facial impressions are an important element of social interaction. Facial impression factors have been investigated mainly by experimental methods, and in recent years, computational approaches have become popular. However, the correspondence between the two is still unclear in many respects. In this study, we explored the factors of attractiveness, dominance, and sexual dimorphism, which are important components of facial impression, using eye-tracking and a deep learning method, gradient-weighted class activation mapping (Grad-CAM), as experimental and computational methods. In Study 1, we used geometric morphometrics to generate many face images with manipulated morphological features. In Study 2, we used these face images in eye-tracking and impression evaluation experiments. In Study 3, we extracted image features important for each impression using Grad-CAM, using the face images generated and labeled in Studies 1 and 2. The results suggest that the eye and nose regions are important for attractiveness, the brow region for dominance, and the eye region for sexual dimorphism, based on the trends in the eye-tracking and Grad-CAM results. We also found that the nose region might be more significant for males when evaluating facial attractiveness. Furthermore, the brow region might hold greater importance for females in evaluating masculinity in males. In this study, combining computational and experimental methods in an exploratory and hypothesis-testing cycle may contribute to understanding of detailed psychological findings. In addition, with the rapid development of deep learning techniques, such an approach is helpful for face research in psychology, especially for examining detailed facial impression factors.
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Towards a process model of temporal preparation

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Events often unfold with a time course amenable to prediction, as when a sprinter gets set to go. This lets us temporally prepare. Classically, researchers have investigated this by manipulating the foreperiod between warning and imperative stimuli. When foreperiods vary randomly within a block, longer foreperiods often yield faster mean reaction times (RTs). This "variable-foreperiod" effect is traditionally explained by considering the conditional probability of an event occurring given that it has not already occurred, formalised by the hazard function. More recently, this function has been derived from how foreperiods are subjectively experienced by the participant (i.e. blurred via a Gaussian kernel that expands according to Weber's law). For commonly used foreperiod distributions (e.g. uniform), this subjective hazard function increases through time, so preparation should similarly increase, and hence reaction times should improve. To date, modelling efforts have demonstrated a quantitative match between mean reaction time across different foreperiods and the (inverted) subjective hazard function (or some related preparation function). However, why expect a linear relationship between preparation and mean RT? Furthermore, modelling at this level provides few insights into how more conceptually meaningful cognitive sub-processes influencing RT are affected. The standard simplifying assumption that the subjective foreperiod distribution is stable also offers no account of sequential effects. To address these issues, here I will present fits to data for a Non-Stationary Poisson model of simple Reaction Time with an initial Stimulus Independent Process (SIP-theN-SPuRT). SIP-theN-SPuRT derives a temporal preparation signal from a subjective foreperiod distribution which is updated trial by trial. This feeds into any or all of three processes, reflecting urgency, modulation of drive from change detectors, and any remaining sensorimotor delays. Hence, in addition to predicting full RT distributions when comparing putative preparation functions, the model may help elucidate the specific cognitive processes that temporal preparation affects.

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Do optical or cortical factors limit the recognition of incomplete letters?

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The Graded Incomplete Letters Test (GILT) was recently developed to detect visual symptoms in dementia, including Posterior Cortical Atrophy (PCA) – a neurodegenerative syndrome predominantly affecting visual brain areas. The GILT measures the threshold for recognising letters under increasing visual degradation, whereby pixelated sections of the letter are removed (decreasing their 'completeness'). Although the GILT can clearly differentiate PCA patients from typical adults, it is unclear why patients struggle to identify incomplete letters. It is particularly important to establish the influence of predominantly optical factors (e.g. blur or reduced contrast sensitivity) versus higher-order cortical factors (e.g. elevated crowding or impaired feature integration) on the task to avoid age-related ocular conditions being mistaken for the visual deficits of PCA. To examine the role of optical factors, we applied blur and lowered contrast separately to incomplete letter stimuli with typical participants (n=6). We first measured blur and contrast thresholds for complete letters and presented stimuli above these thresholds to exclude simple visibility issues. Incomplete letter recognition was then measured, with one of 12 uppercase letters presented foveally for 0.5 seconds on each trial. Participants selected the matching lowercase letter. Stimuli were degraded at different completeness levels using QUEST with a completeness threshold taken at 54.2% correct. Without blur or lowered contrast, average baseline thresholds were around 5% completeness. With optical factors applied, there were small threshold elevations up to 8% completeness near the detection threshold for blur/contrast. Performance then rapidly dropped to baseline with decreasing blur and increasing contrast and remained flat across most of the range. These deficits do not reach the levels

of performance seen in PCA (which can reach 40-80% completeness). Because performance is only slightly impaired near detection thresholds, we argue that poor incomplete letter recognition is more likely associated with cortical factors including crowding and/or feature integration.

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The potential of vibration based self-motion cues in reducing visually induced motion-sickness in Virtual Reality

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Virtual Reality (VR) has become an important tool for research, rehabilitation, and training. However, VR users often report motion sickness-like symptoms, a phenomenon referred to as visually induced motion sickness (VIMS). Although underlying mechanisms are not well understood, a sensory conflict between the visual, vestibular, and/or somatosensory system is thought to be the root of VIMS. To date, reliable methods that successfully prevent or reduce VIMS are lacking. The present project will investigate a novel solution for minimizing VIMS using multisensory stimulation via vibrotactile cues generated by actuators embedded in a vest (Tactsuit X40 - Bhaptics). These vibrotactile cues are designed to correspond to the visual motion shown in VR, providing a multisensory VR experience. We hypothesize that the presentation of matching visual and tactile cues reduces the sensory conflict and thus mitigates VIMS. In addition, we will investigate whether these vibrotactile cues are equally effective in reducing VIMS in younger (18-39) and older adults (65+). Older adults benefit more from redundant multisensory stimulation; we therefore hypothesize that vibrotactile cues will reduce VIMS more effectively in older compared to younger adults. A total of 60 younger and 60 older adults will be recruited (currently tested: n = 35). Participants will be exposed to 15-minutes of passive visual self-motion presented on a VR headset. The motion profile was designed to elicit mild to moderate VIMS, including linear accelerations and decelerations, turns, and rotations around the yaw axis. Participants will experience one of three vibration conditions: directed vibration (vibrations matched the visual motion), undirected vibration (random vibrations), and no vibration (control group). The goal of the present work is to identify an easy-to-apply, effective, and reliable, countermeasures against VIMS that will promote the safety and well-being of VR users. First preliminary analysis with the current sample showed promising results.
Acknowledgements: Mitacs.

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Unveiling the potential of acceleration signals for visual time-to-collision estimation

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Pedestrians typically estimate the time until an accelerating car reaches them (time-to-collision, TTC) based on distance and velocity (first-order information) but tend to neglect the car's acceleration (second-order information). This biased first-order strategy leads to overestimated TTCs for accelerating cars, potentially causing unsafe road-crossing behavior. A previous study showed that a light band around the vehicle's windshield indicating whether the vehicle accelerated could counteract this bias – at least for the specific acceleration rate presented. But does the binary acceleration signal also allow to differentiate between various acceleration rates? The present study compared the effects of two acceleration signals to better understand the processing of acceleration information in TTC estimations, and to provide practical design recommendations. In a VR traffic simulation, thirty participants judged the TTC of approaching vehicles with no acceleration (0 m/s^2), moderate acceleration (1.5 m/s^2), or strong acceleration (3.0 m/s^2). The experiment comprised a prediction-motion paradigm across three blocks: one with a binary acceleration signal indicating whether the car accelerated (light band on/off), one with an informative acceleration signal also conveying the acceleration intensity (light band flashing at lower/higher frequency), and one without any acceleration signal (light band inactive). Our results showed that participants considered acceleration better with the binary signal than without. However, they still failed to consider strong accelerations adequately. Only the informative signal allowed for nuanced TTC estimations, distinguishing between moderate and strong acceleration rates. We conclude that an informative acceleration signal could effectively correct pedestrians' misjudgments of TTC for accelerating vehicles.

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Total masking by 4-dots – objective and phenomenological evidence from a spatial 2-AFC detection task

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Introspective reports of complete elimination of objects from conscious awareness are not uncommon in 4-dot masking experiments. However, there are few studies that have investigated this directly, and the results are inconclusive. To our knowledge, none of the studies in the field to date solely focused on target detection. Either target detection was part of a dual task, or the detection task was presented after a discrimination task using the same stimuli. Other studies presented no-target objects on target-absent trials or the target sans its critical feature, thereby obscuring the distinction between detection and discrimination. Correspondingly, all of these studies used comparatively complex stimuli. As a result, 'target-absent' reports may not indicate complete absence of a conscious percept, but instead result from a reluctance to report 'target-present' when its diagnostic features were not discernible. The current study directly tests whether 4-dot masking can reduce visibility to the point that a masked object is indiscernible from nothingness. In a spatial 2-AFC procedure, participants were presented with Gaussian-Blob stimuli – ruling out any meaningful bias as well as reliance on a particular stimulus feature – followed by two masks, one at a blob-location (target) and one at a previously empty location. Participants reported the target location and also rated the clarity of their target percept (visible, barely visible or not visible). Measures of sensitivity and a Bayesian thresholded-cumulative model based on the visibility rating data confirm that target visibility varied with SOA. Particularly for intermediate SOAs, the probability of reporting the absence of a target percept is high (clearly exceeding 25%), and participants frequently fail to differentiate between the target location and the empty location. Thus, we provide clear empirical evidence, derived

from both objective measures and phenomenological reports, that 4-dot masking can indeed purge an object from perceptual consciousness.

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Somebody's watching me: Exploring the influence of gaze cueing and emotion on self-prioritisation

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There is extensive evidence supporting a self-bias in cognition (i.e., self-prioritisation), where information related to the self is processed with priority (Sui & Rotshtein, 2019, Golubickis et al., 2018; Symons & Johnson, 1997). Indeed, self-prioritisation has been shown to influence decision making, memory, and attention (Anderson et al., 2011; Golubickis & Macrae, 2021; Humphreys & Sui, 2016). For example, the self is found to facilitate executive control (Svensson et al., 2023). However, the relationship between self-prioritisation and attentional orienting remains unclear, with findings suggesting that the self may not directly enhance orienting (Svensson et al., 2023). An alternative approach is to examine whether cueing facilitates self-prioritisation, and gaze cueing provides this mechanism. Specifically, gaze cueing is also found to influence attention, where responses are faster and more accurate towards cued (vs. uncued) locations due to orienting cognitive resources (Frischen & Tipper, 2006; McKay et al., 2021). Addressing this gap, the current research combined an object ownership task with a gaze cueing paradigm to explore whether self-prioritisation is intensified or reduced based on gaze cueing. Moreover, it was explored how negative emotion (i.e., angry vs neutral faces) may interact with gaze cueing and self-prioritisation. It is well established that gaze cueing may increase for emotional faces (e.g., angry faces promote attentional orienting effects; Adams & Kleck, 2003). Interestingly, similar effects have been observed for self-prioritisation. Results revealed an effect of gaze cueing, with faster responses for targets shown at cued (vs. uncued) locations. Participants exhibited higher accuracy in categorising targets for friends than for the self. No interactions were found between gaze cueing, emotion, and self-prioritisation, providing no support for the notion that emotion modulates self-prioritisation or enhances attentional processing. Collectively, these findings emphasise a nuanced relationship between self-prioritisation and attentional processing.

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Congenital Prosopagnosia: Face agnostic but not social-emotional agnostic

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People affected by congenital prosopagnosia (cPA) have considerable problems recognizing people by their faces. There is an ongoing debate about whether they are also impaired in recognizing facial emotions, and even if they are not, they might apply different cognitive pathways. The latter hypothesis is supported by eye-tracking studies that show different visual scan patterns for faces in persons with cPA. In the present study (N=128), participants with cPA had to assign six different emotional facial expressions to six clear-cut emotion categories (neutral, anger, sadness, disgust, fear, happiness; 6-AFC). The additional covering of the lower part of the face by a N95 mask put recognition ability to its limits and would possibly reveal the use of alternate clues for emotion recognition. It was found that the recognition performance and the associated confidence were very similar to adult control subjects (N=99), and this applied to conditions with and without masking. In fact, the data pattern was so similar to the test subjects that we assume that the processing of emotional facial information is not impaired in cPA at all. No indication exists that people with cPA apply alternate cognitive processes for emotion recognition. This supports the view that cognitive processes involved in emotional processing do not directly impact identity processes.

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Spontaneous alternation behavior in Landolt C recognition

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Background. Spontaneous alternation behavior (SAB) is a ubiquitous tendency observed in e.g. human spermatozoa, rodents, human children and adults to alternate their directional choices when encountering consecutive left/right branchings while navigating through a maze. Purpose. The aim of our study was to investigate SAB in a perceptual task, specifically one probing Landolt C recognition in adults. Methods. Twenty adults were tasked with determining optotype orientation in sequences of Landolt Cs displayed on a screen. Stimuli included Landolt Cs in two sizes (+0.15 and +0.3 log arcmin relative to the individual visual acuity threshold) shown in orientations of ±45°, and a below-threshold (−0.30 log arcmin) optotype that was a closed ring and thus had no physical orientation. The aim was to assess whether recognizable Landolt Cs influence responses to subsequent unrecognizable stimuli and trigger SAB. The study also included deceptive conditions, where participants were instructed to respond to the smaller Landolt C as if they could not recognize it. The participants were unaware of the study's purpose and were not informed about subthreshold stimuli being closed rings. Analysis focused on comparing responses to the stimulus of interest with the previous one. Results. In the honest conditions, the frequency of alternating responses to closed rings (i.e., response different from that to preceding Landolt C) was not significantly higher than the frequency of equal responses (P=0.18, P=0.09; P=0.21, respectively). However, in the deceptive conditions, participants exhibited SAB (P=0.03 and P=0.04, respectively). Conclusion. SAB in perceptual tasks in humans appears to exist under certain conditions, namely when the response behavior aims at deceiving.

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Gaze behavior reveals mind-wandering: a virtual reality experiment

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Eye movements can provide insight into how we gather information from our visual surroundings. Most eye-tracking studies have been conducted using 2D images displayed on a computer screen. Modern virtual reality headsets provide high-quality immersive viewing experience combined with the ability to track eye movements. In this study, we had 60 participants visually explore a realistically modelled apartment via a Varjo VR-1 headset. The experiment was implemented in the Unity game engine. Saccades were identified from eye velocity data, and fixations to objects were identified by combining the saccade information with 3D eye gaze data obtained via ray casting in Unity. The number of fixations on each object in the virtual apartment was quantified. Participants had a limited viewing time in each room after which their memory for specific objects was tested. Participants also responded to thought probe questions that aimed to reveal whether they were attentive to the task or mind-wandering. We found that participants who reported more off-task mind-wandering showed more re-fixations to objects that they had already fixated on. In conclusion, our results demonstrate a link between mind-wandering and visual information processing in a naturalistic viewing task.

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'Pathological' Demand Avoidance through the lens of a sensory processing framework

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Sensory processing theories suggest that overlearning about environmental change (i.e., incorrectly learning that the sensory environment is more volatile than it actually is) influences the formation of internal models that are vulnerable to disconfirmation (i.e., representations of the sensory world that frequently deviate from reality). Frequent model disconfirmation theoretically leads to prolonged states of uncertainty and anxiety. 'Pathological' Demand Avoidance (PDA) describes a unique behavioural profile linked to autism that is thought to be primarily driven by uncertainty and anxiety. However, to date, inappropriate volatility learning has yet to be considered as a potential mechanism underpinning these factors in the context of PDA. To determine if it is a mechanism underlying the development of PDA, the present study leverages an individual differences approach in investigating volatility learning in PDA, autistic, and neurotypical groups. We developed a novel probabilistic learning task in which the probability of a cue matching a target is systematically varied. A Bayesian multi-level model was implemented to assess the extent to which RTs can predict scores derived from a descriptive measure of PDA behaviours. Pilot data suggest that aberrant volatility learning is associated with PDA behaviours in neurotypical individuals. These preliminary findings provide initial support for the notion that PDA is associated with a tendency to overlearn about environmental volatility. PDA research is in its infancy; little is currently known about its causal mechanisms. A broader understanding of volatility learning and its relationship to PDA offers a promising line of investigation, providing potential insight into behavioural acquisition and its underlying mechanisms.

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EEG/ERP components underpinning the integration of prior expectations and sensory evidence in social motion perception

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Recent proposals argue that our understanding of other people's behaviour emerges from a predictive process that integrates expectations about those behaviours with the sensory evidence, implementing a process of Bayesian-like hypothesis testing and revision. Here, we present data from two preregistered EEG/ERP experiments investigating the neuronal underpinnings of how people's perception of others' behaviour is influenced by perceptual anticipations of forthcoming actions. Participants observed hand motions towards and away from objects after hearing actors state their intention to "take" or "leave" those objects. The hands disappeared mid-motion and then people reported the perceived disappearance points of the hands on a touchscreen. As expected, and consistent with a Bayesian-like integration process, their reports were predictively biased towards the expected next steps in the motion sequence, and these biases were larger when the motions matched the previously stated action intention, particularly when the intentions reliably predicted the motions. Analysis of event related potentials revealed that the amplitude of the post-stimulus P2 and P3b components closely tracked both the integration of observed motion with prior expectations and determined the resulting perceptual biases. In both experiments, P2 and P3b were larger when observed motions and prior expectation mismatched, linking these components to the hypothesized mechanism for revising of prior expectation in light of conflicting visual evidence. Moreover, trial-by-trial modelling confirmed that the P3b in particular underpins the expectation revision in light of conflicting sensory evidence, reducing the perceptual overestimation towards the expected next steps on the motion sequence. Our results therefore reveal for the first time that P3b reflects the prediction error process, which revises prior expectations towards the sensory evidence, so that these expectations have a reduced influence on perceptual judgments. These findings argue for a framework in which prior expectations – and their revision through stimulus processing – shape social perception.
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Symposium 8 - Peripheral vision: Behavioural, neural & functional perspectives

Information loss in peripheral vision: Crowding, grouping, and redundancy masking

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By far the largest part of our visual field is peripheral. In peripheral vision, as in perceptual systems more generally, information available in the environment is to varying extents selected, discarded, and compressed. Well-known characteristics of peripheral vision are its

lower visual resolution, reduced attention, and stronger crowding compared to central vision. For example, crowding –the deterioration of target identification by flanking stimuli- operates over much larger distances in the periphery. An important predictor of crowding strength is the extent to which the target groups with the flankers: strong target-flanker grouping usually goes hand in hand with strong crowding. Grouping may also underlie the effect of target-flanker similarity: High target-flanker similarity usually yields strong crowding. However, most crowding studies focus on how flankers deteriorate perception of a single target. Recently, we showed how crowding rules did not hold, or were even inverted, for example, when observers reported the entire stimulus (target and flankers) or when target-flanker grouping made the target stand out from the flankers. While the deleterious effect of crowding is often regarded as the main (or only) effect underlying spatial contextual interactions in peripheral vision, these findings show that the generality of crowding rules is questionable. Importantly, previously unknown effects, different from crowding, may go unnoticed in typical crowding paradigms. For example, using appearance-based methods, we recently discovered that the number of perceived items in peripherally presented repeating patterns is reduced: Observers often report seeing fewer items than presented, even if only three items are presented. This compression of redundant visual information, named 'redundancy masking', strongly differs from crowding, and we are only at the beginning of understanding its attributes. Here, we discuss the characteristics and limits of peripheral vision and show how multiple, distinct mechanisms govern appearance and performance in the largest parts of our visual field.
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Neural correlates of visual crowding in the primate brain

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I will present results from a series of experiments investigating how simple scenes with crowding are encoded in midlevel stages of the ventral visual pathway in the macaque monkey. Past studies have demonstrated that neurons in area V4, a quintessential midlevel visual form processing stage, encode the shape of isolated visual stimuli. When these stimuli are surrounded by distractors that crowd and occlude, shape selectivity of V4 neurons degrades, consistent with the decline in the animal's ability to discriminate target object shapes. One prominent hypothesis posits that such crowding effects may be explained on the basis of "pooled" encoding of target and distractor stimuli in terms of summary statistics of the image within the RF. This then results in the loss of visual information and diminished target discriminability. To rigorously test this hypothesis, we characterized responses and selectivity of V4 neurons for a variety of target-distractor relationships. Our results indicate that when a target stimulus is salient relative to the surrounding clutter, either by featural contrast or by perceptual grouping of distractors, pooled encoding of summary statistics fails to explain responses. These results are consistent with an alternative tuned normalization model which enhances V4 encoding of salient stimuli in crowded displays. Overall, our results support the hypothesis that a segmented representation of salient objects begins to emerge in the midlevel processing stages in the primate brain.

Visual periphery is sufficient and necessary for continuous emotion recognition in naturally cluttered dynamic scenes

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Natural scenes are cluttered. This causes crowding, preventing scrutiny and identification of individual objects. Although it has been established that individual objects and features can get through the bottleneck of crowding in some forms, including gist or ensemble perception (Manassi & Whitney, Current Biology, 2018), these demonstrations are limited to artificial stimuli, with limited ecological validity, and the results may not extend to more natural tasks. The question remains: what high level information can humans extract from the visual periphery in more natural, ecologically valid, dynamic scenes? Here we tested whether observers can continuously track and report the emotion of characters in dynamic movies (e.g., Hollywood films and home videos) using only the periphery or only the fovea. In a baseline ground truth condition, observers continuously reported with a mouse the two-dimensional affective state (valence and arousal) of a target character in a film. In the periphery-only condition, independent observers tracked the character's emotion when the fovea was gaze-contingently masked. This left only the visual periphery available (something akin to what macular degeneration might cause), but no information from the fovea. In a fovea-only condition, we gaze contingently masked the peripheral visual field, leaving only the fovea available. We found that having only the periphery available (no fovea) led to surprisingly accurate emotion tracking. However, having the fovea without the periphery led to worse performance. Cross correlating the time series in the two conditions revealed comparable lags, indicating that poorer performance in the fovea-only condition was not simply a problem of visual search or difficulty finding information. The results indicate that the visual periphery is both necessary and sufficient for accurate emotion understanding. More generally, observers can extract rich, high-level perceptual information from the periphery alone, even in highly cluttered natural dynamic scenes.
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Looking versus seeing in peripheral vision

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Vision includes looking and seeing. Looking, mainly via gaze shifts, selects a tiny fraction of visual input information for passage through the brain's information bottleneck. The selected input is placed within the attentional spotlight, typically in the central visual field. Seeing decodes, i.e., recognizes and discriminates, the selected inputs. Hence, the main functional role for peripheral vision is looking rather than seeing, in particular, to decide where to shift the gaze. Looking is often guided exogenously by a saliency map created by the primary visual cortex (V1)(Li 2002), where the bottleneck is proposed to start along the visual pathway (Zhaoping 2019). I will show examples of gaze being strongly attracted by peripheral objects indiscriminable to seeing because of visual crowding or loss of discriminative signals (e.g., eye of origin) beyond V1. In peripheral vision, seeing through the bottleneck not only suffers from poor spatial resolution, but is also subject to crowding and is more vulnerable to illusions from misleading, ambiguous, and impoverished visual inputs. I will show how V1 mechanisms for computing saliency intended for looking create side effects in seeing, such as those manifested in crowding. In light

of the bottleneck, the Central-peripheral Dichotomy (CPD) theory (Zhaoping 2017, 2019, 2024) proposes that seeing employs top-down feedback to query for extra input information; this happens more in central than peripheral vision. Such queries enable central vision to veto misleading feedforward information that cause the illusions. This predicts illusions which are indeed visible in peripheral but not central vision. Furthermore, the theory predicts that compromising the feedback queries renders central vision vulnerable to the same illusions, as confirmed recently in the reversed-depth illusion. The saccades engendered by peripheral vision allows looking to combine with seeing to give human observers the impression of seeing the whole scene clearly despite inattentional blindness.
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Talk Session 12 - Lightness, Brightness & Colour

Radical, experience driven changes in assumed lighting direction are domain specific

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We have previously shown radical changes in the lighting-from-above prior among expert remote sensing surveyors. We now show that these changes are specific to their domain of expertise. Humans exhibit a preference for interpreting luminance cues to surface shape in relation to an assumed overhead light source (the lighting-from-above prior). Expert surveyors at Ordnance Survey (OS, Great Britain's National Mapping Service) maintain a definitive map of Great Britain using stereoscopic aerial images to assess landscape topography and land use. By convention, these images are presented north-up such that the dominant light source (Britain's southerly sun) is directed from below the line of sight: lighting-from-below. We previously asked expert and novice observers to discriminate stereoscopic images of hedges and ditches embedded in strong disparity and luminance noise while systematically varying disparity cues and lighting direction. Sensitivity for lighting direction (above vs below) revealed an altered lighting prior in experts: with some preferring lighting from below. In the current, more naturalistic, study observers were asked to judge the topography represented in dichoptically-presented, noise-free aerial images at one of 8 orientations and to perform a similar task on computer generated images conveying an embossed honeycomb structure via shape-from-shading. Shape/topography judgements varied with image orientation allowing us to estimate the observer's assumed light source. OS experts exhibited a shifted lighting prior relative to novices for the domain-appropriate aerial images but showed no such shift for the artificial honeycomb stimulus. We conclude that changes in the assumed lighting prior induced through long-term experience are domain specific.
Acknowledgements: Funded by Ordnance Survey Ltd (company number 9121572). Emil Skog and Andrew Schofield are recognised as joint first authors.

Lightness illusions show puzzling effects under brief exposure times

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Kaneko & Gilchrist (2020) reported that lightness illusions such as simultaneous contrast or Bressan's Dungeon illusion look different from "normal" when seen in a brief (as 15 ms) flash. Their study implies that the rules governing lightness perception were different at very short exposure times. Continuing this work, we measured the effect of exposure time on the simultaneous lightness contrast, the Dungeon illusion, and Benary's cross. Observers viewed a pair of physically identical targets in the stimulus through a camera shutter, which regulated each exposure time from 16 to 791 ms. We used a within-subject design. Observers reported the lightness of each target by selecting a matching grayscale Munsell chip. We defined the illusion strength as the difference between the two targets' perceived lightness. Results showed that at the shortest exposure time, simultaneous lightness contrast was strongest and Bressan's Dungeon illusion was reversed. The lightness of both illusions varied exponentially with time, plateauing after ~200 ms. However, the effect of Benary's cross did not change over time. Factor analyses suggest that a fast and a slow lightness perception "factor" underlie these effects, with these factors dominating the percept at different timescales. Benary's cross data, however, did not show clear factor structures. Thus, we suggest that lightness perception in a flash heavily depends on "fast" spatially-local (possibly retinal) contrast near the target but this yields with increasing exposure time to a "slow" more cognitive process (such as perceptual grouping and anchoring). Because the triangles in Benary's cross have identical neighbors, local contrast predicts no illusion, yet the illusion was observed in the briefest flash. This suggests that a "slow" process, though perhaps slower in dominating lightness perception than the "fast" process, can still work in a flash as brief as 16 ms.

Perceptual appearance in context: measures and a model

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Suprathreshold lightness depends on local image properties, e.g., luminance, but also on the surrounding context. In simultaneous contrast for example two identical image regions appear different in lightness because of their different contexts. Perceptual matching tasks are commonly used to measure the direction and magnitude of context effects. We recently demonstrated that matching data do not quantitatively capture the interaction between the context and the local image properties. Perceptual scaling methods such as Maximum Likelihood Conjoint Measurement (MLCM) can overcome this limitation. Here we use MLCM to measure perceptual scales for several context effects across a wide range of local luminances. In particular we measure scales for contexts that change local lightness in opposite directions. Assimilation displays make a target look more similar to its background, whereas contrast displays make it look different from its background. Additionally, we aim to predict the scales using a particular model of perceived lightness, namely that of Whittle (1986, 1992). The perceptual scales had clearly identifiable shapes, though with inter-observer differences. For contrast displays, the scales for the incremental and decremental targets were positioned consistently across observers, i.e., increments were perceived as lighter than equiluminant decrements across the scales. For assimilation displays, inter-observer variability was larger, in magnitude and direction of effect, and scales were less consistently positioned across stimuli. Whittle's (1986, 1992) model of contrast and

brightness is a simple parametric model that captures luminance increments and decrements with separate (free) contrast gain parameters. For almost all perceptual scales, it could be fit to capture increments and decrements, although quality of the fits differs idiosyncratically. In conclusion, scales can be estimated using MLCM for different types of context effects, but their consistency depends on the stimulus, and varies between observers. Whittle's contrast gain model predicts scales better where inter-observer consistency is high.
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Dynamical neural model of lightness computation driven by fixational eye movements

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A computational neural model of lightness perception driven by fixational eye movements--elaborated considerably since ECVP 2023--is computer-simulated and shown to account for lightness matches made to Staircase Gelb, simultaneous contrast, and related displays. In Staircase Gelb, a series of papers is presented in a spotlight, arranged in order from darkest to lightest. The paper with the highest reflectance always appears white, and the range of perceived reflectances is highly compressed relative to that of the actual physical reflectances. Reordering the papers also affects their lightness, as does surrounding the series with a white border. In the model, ON- and OFF-center cells with different inherent neural gains (smaller gain for ON cells) respond transiently as the eyes traverse luminance edges in the displays. These transient responses are organized into separate ON and OFF activation maps in visual cortex, sorted by eye movement direction and updated every 100 ms. A second set of ON and OFF maps spatially integrate the activities in the first set of maps with a distance-dependent falloff and taking into account eye movement direction. At a final processing stage, the ON and OFF integration maps are combined to create a single lightness map, which is normalized so that the largest activation in the resulting map always corresponds to white. The lightness map then undergoes leaky temporal integration to produce a spatial map of perceived surface reflectances that depends on neural computations generated across many eye movements. The model explains the psychophysical results described above with <1.5% error, as well the Chevreul illusion, perceptual fading of stabilized images, and quantitative failures of lightness constancy in simultaneous contrast. The assumption that lightness depends on computations averaged across many eye movements requires that the fixational eye movements driving the process must be fast (e.g. ocular tremor) rather than slow (e.g. microsaccades).
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Intermodulation of SSVEPs used to probe bipolarity of colour representations in the cortex

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Colour information enters the cortex via two dominant cone-opponent colour pathways. How colour representations are subsequently transformed in the human cortex is not well understood. We measured intermodulation of steady-state visually evoked potentials (SSVEPs) to characterise the tuning properties of cortical colour mechanisms. Intermodulation components in SSVEP occur at combinations of two or more distinct stimulus frequencies, and are thought to index shared neural resources. We presented isoluminant chromatic checkerboards with colours in odd and even checks that flickered at two distinct frequencies. We characterise cortical colour tuning functions by plotting the amplitudes of intermodulation components as a function of colour dissimilarity between odd and even checks. Amplitudes of intermodulation components weaken as colours become more dissimilar, and their underlying neural representations more distinct. Odd checks were constant S/(L+M) decrements in the MacLeod-Boynton chromaticity diagram, while the chromaticities of even checks varied in hue angle across 12 conditions around the full hue circle. We found 'bipolar' tuning functions with two peaks in amplitude, one where odd and even checks were of the same hue and another where they were of opponent hues. This profile could reflect either the activity of bipolar colour mechanisms, or the activity of rectified monopolar mechanisms responding differentially to stimulus onsets and offsets. We address this question by measuring tuning functions in the presence of selective adaptation of ON and OFF colour mechanisms using sawtooth waveforms. Our study demonstrates how intermodulation of SSVEPs can be used in combination with adaptation to characterise cortical colour mechanisms.
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Memory colors of familiar objects induce general color preference

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Previous studies have offered multiple explanations for the causality of color preference but no consensus has been reached. In this study, we propose an alternative explanation that the memory colors of familiar objects, especially food colors of humans can induce color preferences. We conducted two experiments. In Experiment 1, the memory color experiment, we asked participants to rate the similarity between presented color samples and memory colors of five familiar fruits and vegetables in Japan; we then calculated the location of the colors in the CIELAB color space that looked most similar to the remembered objects using the bivariate Gaussian function. In Experiment 2, the color preference experiment, color variations were created based on the memory colors obtained from Experiment 1. A different group of participants rated their preference for each color variation, then we applied regression analysis to these ratings. We observed two types of regressions between preference ratings and distance to memory colors: (1) for colors from red to green that represent the food colors for primates, color preference increased when the color was closer to the memory colors of the fruits and vegetables found in Experiment 1; and (2) for blue and purple colors, colors were preferred when they became bluer. We suggest that the evolutionarily acquired mechanism of color preference derives crucial cues from our ecological environment. Therefore, the mechanism produces the same color preference trend among people who grow up in similar environments, for example, environments containing the same fruits.

Symposium 9 - Perception, cognition, and action in neuropsychological patients: Bridging science and practice

Impaired body representations post-stroke: insights from drawing and lesion-symptom mapping

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Humans possess the extraordinary ability to produce line drawings that capture detailed information about their perceptual experience of the world. In fact, drawing is a complex skill that engages several cognitive functions including visual perception, memory, imagery and visuomotor control to create recognizable images. As such, this act of visual production provides a powerful tool to investigate how the human brain represents the visual world. Surprisingly most vision research has focused on visual comprehension (i.e., the ability to recognize images) and little is known about the cognitive and neural mechanisms that support drawing ability. Here, we used precision pen-tracking of drawings to investigate how body representations are affected in stroke and how these deficits relate to visual, cognitive and/or motor function as well as lesion location. Eighty-three stroke patients (38 with visual neglect) and thirty-seven age-matched controls were asked to use their intact hand to draw human bodies (self-portrait and another person) and other symmetrical non-human stimulus categories were used as controls (animal and plant). We found that patients with spatial neglect had significant deficits in body drawing, which were especially pronounced during self-portrait, when compared to patients without neglect and age-matched controls. These neglect-specific deficits on self-portraits significantly correlated with the severity of visual neglect and of visual field deficits. Surprisingly, however, these self-body representation deficits did not correlate with measures of personal body neglect. Moreover, we also found that neglect patients had specific impairments in drawing the body of others, but that this global body representation distortion correlated with orientation deficits rather than neglect. The current study suggests that the visual representation our own and others bodies depends on separate neural mechanisms and indicates that the visual attention system is critical for building an accurate body schema.
Acknowledgements: This work was funded by The Stroke Association.

Revisiting the role of left and right hemispheres in action and semantic tool knowledge

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The aim of this work was to better understand the organization of conceptual tool knowledge following stroke. We explored specifically the link between manipulation kinematics and manipulation hand posture; and the link between manipulation kinematics and function relations in left brain-damaged (n = 30) and right brain-damaged (n = 30) patients. We examined the performance of brain-damaged patients in conceptual tool tasks using neuropsychological dissociations and disconnectome symptom mapping. Our results suggest that manipulation kinematics is more impaired than function relations, following left or right brain lesions. We also observed that manipulation kinematics and manipulation hand posture are dissociable dimensions but are still highly interrelated, particularly in left brain-damaged patients. We also found that the corpus callosum and bilateral superior longitudinal fasciculus are involved in action tool knowledge and in a lesser extent in semantic tool knowledge following left brain lesions. Our results provide evidence that the right hemisphere (1) contains conceptual tool representations; and (2) may support the functional recovery through interhemispheric transfer following left stroke. Further studies are needed to better understand the functional mechanisms supporting the cognitive recovery of conceptual tool knowledge.
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A dissociation between object material and material perception: a patient case study

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Knowing the material an object is made of is essential for effectively interacting with that object. For instance, this knowledge allows us to skillfully adjust the grip and lifting forces based on the material properties of the objects. Interestingly, it has been shown that there are regions within ventral temporal cortex that seem dedicated to the processing of material properties. Patient MPS is a 59-year-old right-handed male, who exhibited impaired recognition of object materials following a left ventral temporal lesion. He can flawlessly recognize rectangular blocks made from different materials such as wood, glass, metal, paper, or plastic, but he is impaired at identifying those same materials when associated with manipulable objects presented as words, line-drawings, pictures, or real items. Additionally, when presented with a single object made from different materials (e.g., forks made out of metal, wood, and plastic), MPS had difficulty selecting the requested material. Interestingly, MPS retains an intact ability to perceive the shape, color, size, weight, and function of the same objects for which he struggles to recognize the material. This object knowledge dissociation is reported for the first time and provides insights into specialized regions within the ventral temporal cortex responsible for processing object material. Moreover, it offers valuable information on how visual information of manipulable objects is represented in the brain.

Visual Search in Progressive Supranuclear Palsy and Parkinson’s disease: from fundamental research to diagnostic tool

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Progressive Supranuclear Palsy (PSP) is a rare neurodegenerative disease, affecting 5/100 000 people. It is often misdiagnosed as Parkinson's disease (PD) because it shares many of the motor symptoms typically associated with PD. However, the prognosis and treatment for PSP and PD are very different, and earlier and more accurate differential diagnosis is a high priority for patients. Up to date, the key diagnostic marker of PSP is a restriction of the oculomotor range along the vertical axis. As a corollary, it has been argued that PSP might have an exogenous visuo-attentional impairment within this axis. To test this idea, people with PSP and PD were asked to complete three visual search tasks: easy feature, difficult feature, and conjunction searches. Each of them included three conditions: set size (6 vs 12 items), axis of stimuli presentation (horizontal vs vertical) and target presence (yes vs no). Additionally, participants were instructed to complete a complex cancellation task (Bells test). The results are unequivocal: 1) RTs for the PSP group were significantly longer than those in the PD group whatever the condition, 2) While search slopes for the easy feature task were overall clustered around zero, this cost-per-item drastically increased to 18 ms/item in the PSP group when the target was displayed along the vertical axis, indicating a deficit of reflexive orienting to the singleton, 3) Search slopes for the PSP group were significantly steeper than for the PD group in the difficult feature and conjunction searches when the target was absent, although effect was modulated by demographics and neuropsychological profile, and 4) In the Bells test, a composite score combining search duration and omissions was able to discriminate efficiently both clinical populations (sensitivity: 0.97; specificity: 0.87) independently of demographics and neuropsychological profile, confirming its potential as tool for differential diagnosis.
Acknowledgements: Dunhill Medical Trust.

Using Augmented Reality to assess spatial neglect: the Free-Exploration-Test (FET)

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Background: Spatial neglect is a disorder following right hemisphere brain injury, resulting in a bias of exploratory activity toward the side of the lesion. To capture this bias, traditional diagnostic methods and new virtual reality applications use confined workspaces that limit patients' exploration behavior to a predefined area. Our aim was to overcome these limitations and enable the recording of patients' biased activity in real, unconfined space. Methods: We developed the Free-Exploration-Test (FET) based on augmented reality (AR) technology. Using a live stream via the back camera on a tablet, patients search for a (non-existent) virtual target in their environment while their exploration movements are recorded for 30 seconds. We tested 20 neglect patients and 20 healthy participants and compared the performance of the FET with traditional neglect tests. Results: In contrast to controls, neglect patients exhibited a significant rightward bias in exploratory movements. The FET had a high discriminative power (AUC = 0.89) and correlated positively with traditional tests of spatial neglect (Letter Cancellation, Bells Test, Copying Task, Line Bisection). An optimal cut-off point of the averaged bias of exploratory activity was at 9.0° on the right; it distinguished neglect patients from controls with 85% sensitivity. Discussion: FET offers time efficient (execution time: ~3 min), easy to apply, and gamified assessment of free exploratory activity. It supplements traditional neglect tests, providing unrestricted recording of exploration in the real, unconfined space surrounding the patient.

Symposium 10 - From eye movements to action: Celebrating Eli Brenner's contributions to the field of Perception and Action

Temporal dynamics of foveal and peripheral processing during fixation

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When inspecting visual scenes, we combine saccades with short fixation periods in which the eyes remain relatively stable. During fixation, foveal and peripheral information is processed, and being able to detect and localize changes at either location is fundamental for survival. However, the temporal dynamics of foveal and peripheral sensitivity upon saccade landing, during fixation, remains unknown. To investigate this, we asked participants (n=8) to make a saccade from an initial fixation point that appeared in the lower part of a screen towards a central fixation point. The central fixation point was surrounded by four bars that in different conditions could be located either all in the fovea (0.3º of eccentricity), all in the periphery (9º of eccentricity), or two in the fovea and two in the periphery. The peripheral bars were enlarged to compensate for cortical magnification. At any given moment during participant's fixation, one of the bars briefly (50 ms) changed its orientation. The change in orientation was chosen so that in yielded 80% correct responses for each participant and bar location when the change occurred 490 ms after saccade landing. At the end of the trial, participants had to indicate which of the bars had moved. Our results show that when all stimuli were in the fovea, the ability to detect the change remained similar during fixation (68±5% vs 75±5% for changes happening 100-250 ms and 750-900 after fixation onset, respectively). When all stimuli were in the periphery, performance clearly improved during fixation (55±5% vs 77±2% for early and late changes). Results were similar when participants had to monitor simultaneously foveal (72±6% vs 72±5%) and peripheral (61±4 vs 80±3) stimuli. These findings suggest that our ability to localize changes in a scene varies during fixation, and that such modulation differs for foveal and peripheral stimuli.
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Eye movements and prediction: from following dots to understanding motion

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In 1961 Cyril Rashbass published a paper that determined the way smooth pursuit eye movements were studied ever since. In the step-ramp paradigm, a small spot abruptly steps to one side, then returns to the starting point and continues in the opposite direction. When the initial displacement allows the spot to reach the fixation point in approximately 200 ms, observers' eyes smoothly accelerate to follow the spot's motion, without requiring corrective saccades. In natural viewing, this situation hardly ever occurs. In the real world,

smooth pursuit is always preceded by a saccadic eye movement, and the object being pursued is embedded into a scene. Therefore, we studied the interaction of saccadic and pursuit eye movements, and the effect semantic context has on oculomotor following. In a series of experiment, we showed that corrective saccades have an immediate beneficial effect on subsequent pursuit gain. Saccades to moving targets use motion prediction to land exactly on target, except when that motion information is compromised, as is the case for isoluminant targets. Post-saccadic pursuit direction and speed were minutely adjusted depending on the saccadic landing position. Despite all this optimization, there is a considerable delay of about 200 msec when tracking unpredictable movements. However, embedding such motion within a relevant scene context, exemplified by using annotated ice hockey videos in our studies, eliminates this delay. This suggests that the brain leverages semantic context to predict continuous motion, thereby optimizing eye movement. In conclusion, our findings highlight a divergence between oculomotor behavior in controlled experiments and natural viewing. Contextual understanding significantly influences target tracking, suggesting that the primary goal of eye movements is to ensure timely fixation on relevant points, rather than minimizing retinal error during predictable motion phases.
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Perception of position and motion: dependent but inconsistent

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Already since his Utrecht period, Eli Brenner has been interested in motion perception. This topic combines two recurring factors in Eli Brenner's work: the inconsistent perception of related attributes and the stable interpretation of ambiguous signals. In this presentation, I will shortly review some of the work we did on inconsistencies in the perception of position and motion, and how these inconsistencies shape interception movements. I will end with new work on how the ambiguity of afferent and efferent signals on eye orientation leads to a subtle illusion: static eye orientation influences motion perception.

What are the implications of dissociating user and tool orientation on remote tool use?

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Over the years human-computer interaction using computer mice and joysticks has evolved into more sophisticated remote control, such as telerobotic surgery or deep-sea exploration. Proficient use of such technologies requires learning, as this remote control breaks the direct interaction with the world that humans are attuned to. This can introduce complex dissociations between the user and the tool they are controlling. One example of this is that the relationship between the user's movements and the tool's movements change as a function of the tool's orientation relative to the user. Does the extent of this dissociation affect visuomotor learning and control? To answer this question, we developed a novel control system that participants were not familiar with. Participants' body movements were measured in real-time using pressure sensing technology to control the movements of either a robot moving through a maze in the real world or a virtual avatar on a computer screen. Sometimes, the user and tool were in the same orientation such that there was no dissociation. However, the tool could rotate such that its orientation gradually became more dissociated from that of the user. We captured participants' expectations regarding the mapping that converted their movements into those of the tool during a pre- and post-calibration period. Most participants expected the mapping to be coded in a user-centric reference frame such that the tool's orientation was irrelevant; this was not the case. Participants learnt to control the movements of the tool, evidenced by faster and more direct movement paths over the course of the experiment. There was considerable variability in both learning rate and strategy across participants. One consistent finding, however, was that introducing a dissociation between user and tool orientation impaired visuomotor control. We conclude that user expectations should be considered during the design of remote-control interfaces.

Overconfidence about sensory precision in multisensory integration

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Sensory measurements are noisy; estimates of world properties (e.g., the location of a viewed object or a sound) vary over repeated instances. Estimation improves by integrating multiple sources of information such as seeing and hearing an object in the scene. To minimize uncertainty, an ideal observer will average the measurements from each modality, weighting each proportional to its reliability (inverse variance). But, one should only do this if one is certain the signals derive from the same source in the world. Thus, another inference comes into play: inferring the probability that the two signals derive from the same source. We ask whether humans use an accurate value of their uncertainty to optimally perform causal inference and cue integration. Participants completed a series of discrimination and estimation tasks with auditory, visual and audiovisual stimuli varying in spatial location and/or timing. In the cue-integration task, we presented participants with a visual (a Gaussian blob) and an auditory stimulus (a brief burst of white noise) with various spatial and temporal discrepancies between them. Participants localized the auditory stimulus and then reported whether the two stimuli originated from the same source. Spatial ventriloquism effects were reduced for large spatial or temporal discrepancies, consistent with causal inference. Bayesian ideal-observer models were fit jointly to the results of all tasks. The set of tasks was designed so that we could estimate both the true spatial and temporal uncertainty in each modality as well as, in some models, the estimate of uncertainty used for inference. We performed model comparisons and analyzed the best-fitting parameters and found that, in both unimodal and bimodal contexts, participants' inference relied on overconfident estimates of auditory spatial and temporal uncertainty. These findings challenge the assumption that human behavior optimally accounts for sensory uncertainty regardless of sensory domain.
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Talk Session 13 - Serial Effects

Neural tuning curves for spatial frequency in past and present stimulus representations

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The perception of current stimuli can be influenced by the recent past. Such effects can be repulsive (e.g. adaptation) or attractive (e.g. serial dependence). The current study aimed to track the brain correlates of such history effects by re-analyzing a public EEG dataset (Grootswagers et al., 2024, PLoS Computational Biolology) in which participants passively viewed a stream of visual stimuli. Stimuli differed in visual features, notably spatial frequency (SF) with four levels from high to low. Using MVPA, it was possible to decode the SF of the current stimulus, replicating the original work. Classifiers trained to distinguish between any two SF levels (for example, the lowest from its closest neighbor) were then able to cross-classify other SF differences proportionally to their physical difference. Thus, best classification performance was not necessarily observed when testing the trained classes, but as a function of the physical difference between classes. This shows that the classifier identified a neural representation proportional to spatial frequency, similar to neuronal tuning curves and population receptive fields. Traces of the past SF tuned to stimulus characteristics were also decodable in the response to current stimuli, providing a candidate neural representation for history effects.

Individual differences reveal similarities in serial effects across perceptual tasks, but not to oculomotor tasks

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Serial dependence effects from one trial to the next have been observed across a wide range of perceptual tasks, as well as for oculomotor behavior. This opens up the question of whether the effects observed across all of these studies share common underlying mechanisms. To adress this, we measured the same group of observers (N = 40) across four different tasks, two perceptual (color judgments and orientation judgments) and two oculomotor (tracking of moving targets and the pupil light reflex). On the group level, we observed significant attractive serial dependence effects for all tasks, except the pupil response. The rare absence of a serial dependence effect for the reflex like pupil light response suggests that sequential effects require cortical processing or even higher-level cognition. In the following step, we leveraged reliable individual differences between observers in the other tasks to test whether there is a trait-like behavior of some observers showing stronger serial dependence effects across all of these tasks. We observed a significant relationship in the strength of serial dependence for the two perceptual experiments, but no relation between the perceptual tasks and oculomotor behavior. This indicates, differences in processing between perception and oculomotor control and the absence of a general trait-like behavior that affects all tasks similarly. However, the shared variance in the strength of serial dependence effects across different perceptual tasks indicates the importance of a similar positive decision bias present, that is reliably different between observers and consistent across different perceptual serial dependence tasks.

Attention works as a filter for prior perceptual decision in serial dependence

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Our perception reflects current sensory evidence but also the history of our previous perceptual decisions. This phenomenon is called serial dependence and is based on the assumption that the world around us is sufficiently stable and a recently made perceptual decision can be used as a supplementary source of information to reduce the uncertainty. In the case of numerosity judgments, this means that responses for the same stimulus will be higher if it is a part of a descending sequence, as the preceding value is always larger biasing perception upwards, than for an ascending sequence. We tested this using a numerosity judgment task where participants had to estimate the numerosity of briefly presented dots either in full or divided attention conditions. We observed a strong serial dependence both in single and dual tasks. To quantify the effect of prior perception and attention, we used a modified Bayesian integration model that assumed (1) a non- monotonic relationship between numerosity and uncertainty, (2) a Gaussian distance measure between numerosity levels with a scale parameter controlling the relevance of prior decision for the current trial, i.e., smaller scale values mean that only nearby numerosity values are included into the decision, whereas large scale values mean lack of selectivity as any prior numerosity is included. We report that (1) overall uncertainty was the same for both attention conditions, (2) the weight of prior evidence was higher during poor attention blocks, (3) high selectivity (small values of scale parameter) during full attention but virtually no selectivity of prior evidence during poor attention. To summarize, consistent with the idea of attention as a filter, we found that although the prior perceptual decision was used with both full and poor attention, in the latter case it was used indiscriminately, irrespective of its relevance to the current judgment.

The role of stable and unstable environments on serial dependence

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Perception and decisions are heavily influenced by previous information. Studies in the field of serial dependence revealed strong attractive biases towards previous stimuli. Even if the current visual input is uncertain, it is likely to be similar to what we previously saw. Hence, incorporating information about prior and present stimuli is advantageous when constructing mental representations. While uncertainty in the current information drives the strength of serial dependence, recent results also showed that the uncertainty of previous information is generally ignored. Uncertainty appears to not be integrated optimally. In this current study, we show that a form of optimal integration occurs when sequentially presented information is stable over time. Observers passively watched sequences of 4-9 Gabors and were asked to replicate the orientation of the last Gabor in the sequence. Gabors either had high or low spatial frequencies, and the frequencies of the last two Gabors in the sequence were selected so that it created the four possible uncertainty combinations. Crucially, the uncertainty of all other Gabors in the sequence was either constantly high or low, or was randomly chosen. Moreover, orientations of all Gabors in the sequence were drawn from a narrow range of orientations. This resulted in only small orientation changes from one Gabor to the next and in a stable continuous input. Our results confirm that the strength of serial dependence depends

on the uncertainty of the current trial. We observed no difference between the random and unstable uncertainty conditions. Crucially however, we found that uncertainty was optimally integrated when the uncertainty of the last Gabor was low. Using similar orientations over longer sequences appear to induce optimal integration of past and current information, potentially introducing the continuous perception of a single object. High uncertainty Gabors continuously induced strong serial dependence irrespective of the previous uncertainty.

The broad utility of asymptotic regression in accounting for time effects

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All perception has a temporal context, whether we are interested in it or not. For example, many perceptual phenomena, such as adaptation and aftereffects, grow or dissipate over time. Experiments also tend to involve multiple trials and performance generally improves throughout the course of the study, particularly in early practice trials. The effects of time often take a similar form: monotonically decreasing or increasing towards an asymptote. In these cases, the mean as a summary statistic will be dependent on the time interval of the measurement. For example, with a low number of trials in a response time task, the mean will be biased towards early (slower) trials. As the number of trials increases, the mean will decrease towards an asymptote. By modelling the asymptote explicitly, we obtain statistics that are independent of the number of trials. Accounting for how behaviour changes dynamically can contribute to theory development. But whether behavioural dynamics are the object of study or a nuisance variable, their inclusion in models of data makes conclusions more complete, robust and well-specified. Asymptotic regression is a relatively simple tool that can be applied to time series data to estimate three parameters: starting point, rate of change, and asymptote. Each parameter has a meaningful interpretation in terms of ecological validity, learning and performance limits, respectively. We demonstrate the utility of asymptotic regression over a range of paradigms including Stroop and visual search. In addition to providing a more accurate model of performance in these examples, we show how this approach provides principled answers to many common methodological questions (e.g. how much practice is sufficient? How many trials should I run?).

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The economy of neural responses to predictable sequences of stimuli: Resource-efficient encoding and sharpening

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How does the brain process highly predictable sequences of visual stimuli? In this study, we employed EEG steady-state visual evoked potentials (SSVEP) along with the phenomenon of representational momentum (RM) to investigate the neural mechanisms involved. In RM, perceptual decisions are biased towards the future direction of a rotating stimulus, reflecting the tendency of the human brain to anticipate future states of predictable stimuli. Participants were instructed to attend to one of two sequences of 5-Hz flickering Gabor stimuli simultaneously presented in the two hemifields: one containing an RM-inducing rotating sequence of orientations (predictable) and the other containing random orientation changes (random). When participants attended to the random sequence, we found a strong lateralization of 5-Hz SSVEP power, increasing contralaterally to the attended side. Conversely, when participants attended to the predictable sequence, we observed a robust RM effect on behavior, but no lateralization of SSVEP activity. 5-Hz power contralateral to the attended side was significantly reduced when participants attended to the predictable sequence compared to the random sequence, suggesting reduced engagement of neural resources. Despite this, inverted encoding modeling (IEM) revealed intact orientation representations in the predictable condition, with sharper decoder tuning functions exhibiting a systematic bias along the future trajectory of rotation. These findings suggest that the brain leverages internalized dynamics to maintain reliable 'anticipatory' representations of predictable sequences with little attentional cost and encoding resources. We discuss this view as an alternative to traditional predictive coding theories, which emphasize top-down prediction signals and prediction-error minimization in sensory processing areas.

Talk Session 14 - Individual Differences

Individual Differences in Colour Naming

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Colour naming is partly driven by the need for inter-individual communication of perceptions. Here we quantify individual variability in colour naming within and between distinct colour vision phenotypes. Methods: The task, part of a larger battery of colour vision assessments including diagnosis of X-linked colour vision deficiencies (CVDs) via Rayleigh anomaloscope, was free colour naming of 140 paper samples under daylight illumination. Participant groups included normal trichromats (NT) (N=23; 14 females) and individuals with distinct CVD phenotypes: deuteranomalous (DA) (N=13 males); protanomalous (PA) (N=6; 1 female); deuteranopic (DD) (N=5 males); and protanopic (PD) (N = 6 males). Group mean ages varied from 27-35. We quantified the variability of individual colour naming against normative data either from the same or a different group (within- or between-groups). Normative data included frequency of different types of colour term use (e.g. Basic Colour Terms (BCTs), Non-BCTs, and modified BCTs) and individual specific term use for the sample set. We computed the concordance of an individual's colour name for a given sample in terms of the probability of that name being used for that sample by the defined population. Results: Individual variability with respect to all measures is high in all groups. In all groups, the most common term type used is BCT and the second most common is modified BCT. NTs are more likely to use non-BCTs than all CVD groups. All CVD groups show greater within-group variability than TDs but lower between-group concordance when compared against the TD norm, with the lowest between-group concordance occurring for dichromats (DD and PD). In the CVD groups, the lowest

concordance occurred for the most chromatic colours. Conclusion: Individual variability in colour naming is affected by factors at both the retinal and higher levels, possibly related to variations in the perceived need for colour communication.

Experts don't adapt! The flexibility of non-face animate object representations depends on expertise

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Adequately perceiving animacy is essential for human cognition and survival. The perception of human faces (a subclass of animate objects) is extensively studied due to their high social relevance. Findings show that their representations are not stable but adapt flexibly to recently encountered sensory information, resulting in measurable aftereffects. Further studies examining the animate – inanimate distinction show that the cognitive system prioritizes animate objects in general. But how do we distinguish animals from each other? Are the representations of non-face animate objects also flexible? And what are the effects of perceptual learning and expertise? To tackle these questions, we created biologically plausible stimuli of crustaceans (systematically manipulated images of crabs and lobsters) for two experiments with six participant groups at increasing levels of zoological expertise (naïve students, biology bachelor, master's, and PhD students, post-docs, and professors). Experiment 1 tested the role of body shape in a categorization task. The latter three groups provided more accurate ratings, indicating the effects of expertise. Reaction times revealed strong typicality effects regarding certain body shapes across all six groups, implying that some properties of the underlying concepts are so inherent that not even expertise will overwrite them. Experiment 2 explored the possible influence of expertise in an adaptation paradigm. We found a negative relationship between the magnitude of adaptation aftereffects and the level of expertise and, in fact, no aftereffects among post-docs and professors. This establishes not only the flexibility of non-face animate object representations but also the stabilizing effect of expertise, making their representations – unlike of faces – more accurate and resistant to immediate influences. Since professors' and students' RTs were similarly short, expertise also appears to help counterbalance the normative age-related cognitive decline. Thus, our findings extend the phenomenon of flexible representations and the influence of expertise beyond human faces.

Do we really measure what we believe we are measuring?

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Representative paradigms and tests are crucial in all empirical sciences, which are supposed to measure the characteristics of an underlying latent variable or scientific construct. For example, Snellen E and Landolt Cs are both thought to be representative for visual acuity. Obviously, a test would be useless when its performance does not correlate with the performance of similar tests. Here, we will show first that, contrary to this assumption, in a cohort of 104 young participants, performance in 20 classic vision tests, including Landolt Cs, Gabors, and Verniers, only weakly correlated with each other. Second, we added a cohort of 92 older adults who performed the same tests, and found that the older adults performed clearly worse than the younger participants. We assumed that an older participant, who excels in a specific vision test, will excel in all tests or at least in similar ones because, for example, the participant has less lens clouding than other participants. However, this was not the case. Performance in the various tests was largely uncorrelated, even though test re-test reliability was good and variance was high (i.e., the reliability paradox does not apply). Hence, even though there is a large group difference between younger and older participants, there are almost no significant correlations within the older group. These results suggest that tests are often less representative than previously thought. We will show that these paradoxical results can be explained by the fact that true inter-participant variability drives inter-individual performance differences in the tests but not, as often assumed, measurement noise. We will discuss the implications for science in general.

Exploration of individual differences in search strategy

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Our foveated visual system necessitates eye movements in order to process high resolution details. To evaluate whether healthy human observers allocate eye movements that maximize information gain, we divided the screen into two halves so that the target is easy to see to one side of the screen centre and requires eye movements to verify target presence on the other (hard) side. Using this task, we have consistently shown large individual differences in visual search efficiency defined as proportion of fixations to the hard side. In a recent large-scale pre-registered eye-tracking study (n=267, Clarke et al., 2024), we tested if the tendency to allocate eye movements inefficiently can be related to personality characteristics, or to a general tendency to act without considering larger goals. This was not the case. We will present a further exploratory analysis of this dataset by examining the other types of visual search behaviours, such as fixating on the target without reporting it as present, or repeatedly revisiting the same locations. We will show to what extent these errors correlate with search performance metrics including reaction time (RT), accuracy, and previously defined measures of search efficiency. Additionally, we will discuss the extent to which the organization of participants' search strategies, ranging from disorganized to structured, correlates with behavioral indicators of efficiency or personality characteristics.

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Inter-individual variability in visual evoked potentials is not noise

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Neuroscientists, classically treat visual evoked potential (VEP) inter-individual variability as a nuisance and eliminate it by aggregating individuals (grand-group average) or by reducing the waveforms to few summarizing features (peak amplitude and latency). As a consequence, the conclusions made on group-level canonical waveforms do not always generalize well to individuals. To illustrate this, let us consider visual backward masking (VBM). At the group-level, this well-established paradigm elicits in the visual cortex a late N1

component at around 200 ms after the onset of the target stimulus and is used to study sensory processing and selective attention. We used global field power (GFP) to summarize the global activity over all recording electrodes at each time point and found highly stable group average GFP waveforms and N1 components after 5 and 10 years using a longitudinal cohort of schizophrenia patients and healthy controls. However, we also observed a remarkable diversity of GFP waveforms across participants, with a majority exhibiting substantial deviations from the group-level average. For example, we noticed important variations in the number of peaks, latencies and amplitudes of N1 and interestingly, those variations remain very stable after 5 and 10 years. The high intra-individual stability suggests that the inter-individual differences in VEP contain meaningful information about the subjects which could notably be explained by variations in anatomy and/or cognition.

Eye-Tracking Study on Attentional Allocation to Biological Motion in Children With/Without Autism Across Ages

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Background: Individuals with autism face difficulties with social interaction frequently attributed to challenges in interpreting human movements and others' emotions. Objective: To examine how children with autism spectrum disorder (ASD), compared to typically developing (TD) children, attend to different regions of a person engaged in biological motion, whether attention allocated to a specific body region differs depending on emotion recognition, and how these gaze patterns vary by age. Methods: Children 4 to 12 years with ASD (N=45) and TD-matched controls (TD; N=44) viewed point-light-displays consisting of markers placed on different body regions (e.g., limbs, shoulders, pelvis, and head) that showed 15-second animated movements of the body in three dimensions expressing three emotions (anger, fear, happiness, or neutral) and a non-emotional control condition (rotation of a still human form), recorded via- eye tracking technology. Statistical Analyses: Linear mixed models modeled the percentage of time spent looking at ROIs (%Region) as a function of factorial fixed effects of Group (ASD or TD), Condition (Anger, Fear, Happy, Neutral, or non-biological Rotation), Region (Upper Center, Lower Center, or Extremities), and Age Group (Younger or Older). Results: Few differences were evident between younger children with ASD and TD children. However, older TD children looked more toward regions of the biological motion figure corresponding to the figure's upper center (head), whereas older children with ASD looked more toward the extremities. Furthermore, attention allocation was more significant in the emotion animations of the extremities' regions in the older ASD group than in TD. Conclusions: Findings suggest developmental advances in social-information biases in TD children, not evident in children with ASD, together with atypical and potentially adaptive increases in attentional biases towards local motion cues with age in ASD.

Talk Session 15 - Eye Movements

Cortical Mechanisms for Trans-saccadic Feature Integration

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In natural conditions, humans make several saccades per second. To allow for continuous, uninterrupted perception, this necessitates cortical mechanisms for retention and integration of information across visual fixations. Further, transsaccadic integration imposes specific 'binding problems' across cortical modules, potentially including communication between dorsal and ventral streams, and between hemispheres when saccades reverse the retinal hemifield of stimuli. Previous research suggests that transsaccadic updating of spatial features (location, orientation) occurs in posterior parietal cortex, whereas intrinsic object features (e.g., spatial frequency) are processed in dorsomedial occipital cortex. Two remaining questions are 1) how does the transsaccadic system process these multiple features simultaneously, and 2) how this influences the modularity and network dynamics of the system. Here, we address these issues using fMRI data measured while 17 human participants discriminated whether an object's shape or orientation changed, with or without an intervening saccade across the object. A region of interest analysis confirmed transsaccadic orientation modulations in right parietal cortex and shape modulations in dorsomedial occipital cortex. We then applied graph theory analysis to BOLD timecourses from 50 vision-related cortical nodes identify local and global network properties. Modularity analysis revealed three sub-networks during fixation: a bilateral 'visuospatial' module in parietofrontal cortex and two lateralized occipitotemporal networks linking areas implicated in intrinsic feature processing. When horizontal saccades required comparisons between the left and right visual hemifields, information transfer increased within the network, and the two lateralized ventral modules became functionally integrated into a single bilateral sub-network. This network included 'between module' connectivity hubs in lateral intraparietal cortex and dorsomedial occipital areas implicated in transsaccadic integration. These results confirm the special roles of occipital and parietal cortex in transsaccadic integration, provide objective support for functional modularity within the cortical networks for vision, and show how hemispheric sub-networks are modified and functionally integrated during saccades.
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The Effect of Sound on Visual Stability Perception During Saccades

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Human observers make saccades (large shifts of eye gaze) frequently as we explore the world visually. Despite drastic changes in visual inputs due to eye movements, we perceive a stable visual world and do not notice motion blur; this is called saccadic suppression. Saccadic suppression of stimulus displacement (SSD) is one variety of saccadic suppression closely related to visual stability, and might be explained by the assumption that the world is stable. Importantly, such an assumption could be altered by non-visual signals like sound, even without a change in visual stimulation. Here, we empirically tested this hypothesis that sound serves as an effective cue to

signal changes in the visual world, moderating our perception of visual stability during eye movement. Human observers (n = 16) participated in a lab-based experiment in which they reported whether a visual target jumped to the left or right (0.33 deg) when they made a saccade. Critically, a sound was presented synchronously with the visual target, with a 100-ms gap at the time of saccade (audio-blank), potentially signalling a change in the visual event. Other times, the sound was constant (audio-no-blank, signalling no change) or absent (silent). Results showed that observers' ability to discriminate target shift direction was improved under the audio-blank condition, relative to the silent condition ($p = .002$), and the audio-no-blank condition ($p = .037$). Subsequent control experiments showed that presenting the sound asynchronously with visual target onset—disrupting audio-visual integration—weakened the effects of sound. These results highlight an auditory counterpart of the visual blanking effect of saccadic suppression, where a brief gap of the visual target at the time of saccades leads to better visual discrimination. Our work supports the role of audio-visual integration in mediating extra-retinal explanations of visual stability perception during saccades.
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Unlocking the Diagnostic Potential of Eye Movement Tasks

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Patients with cognitive decline are often referred to memory clinics. Within memory clinics patients can be diagnosed with a variety of issues which effect cognition, including Alzheimer's disease, mild cognitive impairment (MCI), post-concussion syndrome (PCS), functional cognitive disorder (FCD), etc. Following diagnosis interventions can be used, but each intervention is specific for each diagnosis. Therefore, efficient diagnosis enables interventions to be utilised sooner and reduce impairments before they may become permanent. Our previous research has demonstrated that eye movement tasks can be used to help differentiate patients with cognitive decline. Our research indicates that early-stage Alzheimer's disease can be differentiated from healthy individuals by antisaccade eye-movement, with subtypes of MCI also differentiated. We also demonstrated the advantage of these eye movement tasks in participants from different ethnic and cultural backgrounds. We now report new research which indicates that saccadic eye movement tests can also be used to screen for FCD, a functional cognitive condition which is traditionally difficult to differentiate from organic causes. Antisaccade results indicated that FCD differed significantly from MCI but not from heathy controls, but FCD did differ significantly from healthy controls in prosaccades. Additionally, we also report that smooth pursuit tasks can be used for PCS. Participants with PCS (athletes following a concussion) could be differentiated from matched-controls. Moreover, we have also developed smartphone eye tracking systems which enable these tasks to be performed in clinical settings without the need of expensive eye tracking equipment. Overall these results indicate that different eye movement tasks can aid clinicians in clinical diagnosis of a variety of issues affecting cognitive decline. With additional research into sensitivity and specificity, eye movement tasks could become an important feature of memory clinics.

Perisaccadic visual sensitivity during saccadic gain adaptation

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Saccadic eye movements are preceded by shifts of visual attention to their target locations, but the exact nature of the relationship between oculomotor programming and attention is still debated. On the one hand, it has been suggested that visual attention is a prerequisite of motor programming and selects the saccade target among competing stimulation. Conversely, saccade preparation may drive attentional orienting. According to the latter view, a modification of the oculomotor program, however gradual and unconscious, should elicit a corresponding change of the pre-saccadic locus of attention. To test this deduction, we experimentally dissociated the intended saccade goal from the actual saccade endpoint via saccadic gain adaptation: By systematically displacing the saccade target in- or outward during the eye movement, saccade amplitudes were altered by up to 20% of the original vector. Using a dynamic 1/f noise discrimination paradigm, which allows to asses perceptual sensitivity across the visual field, we tracked the focus of attention during saccadic adaptation. Visual sensitivity within ~100 ms before saccade onset—taken as proxy of presaccadic attention—was unaffected by the continuous modification of the saccade vector, and remained highest at the original, intended saccade goal (as compared to the adapted saccade endpoint). Our results suggest that movement preparation—at least its stages that are affected by adaptation—does not control attentional orienting. Interestingly, even though presaccadic attention resisted saccadic gain adaptation, postsaccadic sensitivity was highest at the actual (adapted) landing position right after saccade offset. Our results thus uncover a rapid trans-saccadic updating process that ensures a continuous alignment of the focus of attention with the movement target, from its presaccadic location to the postsaccadic center of gaze.
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Environmental regularities are predictive of saccade direction biases via combination of allocentric and egocentric mechanisms

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Saccadic eye movements shift the fovea onto objects of interest to create a perception of a visual scene. In humans, saccades are predominantly executed along the cardinal axes, particularly in the horizontal direction. It is unclear why the horizontal saccade bias exists. Here we tested the hypothesis that the saccade bias exists in part due to orientation biases present in natural images combined with egocentric saccade generation biases. We used two publicly available datasets: one that contained eye movement data from 29 observers across 101 unique images, and another that contained data from 20 observers across 40 unique images that could be tilted -30°, 0° or 30°. We analyzed the orientation bias present in these images according to their statistical orientation energy, saliency, and structural content before implementing a linear regression model that included one behavioral outcome variable and three image-based predictors. The analysis revealed that the horizontal saccade bias is best predicted by orientation biases in saliency content. However,

saliency alone cannot explain saccade direction distributions since previous work has shown that saccade direction distributions do not reorient fully in response to image tilt or head tilt. To examine how a saccade direction bias may be neurally instantiated in the brain, we implemented a model of saccade target selection that combined allocentric biases aligned with the image orientation and egocentric biases aligned with eye or head orientation. We found that this model simulated saccade distributions that more closely resembled those of saccades made by real humans in response to image tilt than ones generated by saliency alone. Taken together, these results suggest that saccade generation reflects both the allocentric biases present in the orientation statistics of natural scenes and the egocentric biases present in the saccade generation system itself.
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Reward-based modulations of saccade kinematics shape the time course of presaccadic attention

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Saccades are quick, ballistic eye movements characterized by consistent movement patterns: as their amplitude increases, so do their duration (linearly) and peak velocity (exponentially), a consistent relationship referred to as the main sequence. Additionally, each saccade is preceded by a shift of presaccadic attention to the saccade target location. Here, we used a novel trial-based monetary reward paradigm to study simultaneously the reward-related modifications of saccade kinematics and their potential impact on presaccadic attention. On each trial, a cue indicated one of three possible saccade target locations. At various intervals preceding the saccade, a grating was flashed for 25 ms at the saccade target location. Participants saccaded to the target, were informed about the reward they received, and reported the orientation of the grating. The monetary reward was contingent on saccadic peak velocity (up to 5 cents), rather than discrimination performance. In different blocks, participants were rewarded either for making fast or slow saccades. In blocks rewarding fast movements, saccades had significantly higher velocity than in blocks rewarding slow movements. Simultaneously, we observed a shift in the time course of presaccadic attention. Compared to rewarding fast saccades, rewarding slow saccades revealed a significant disadvantage in performance just before the saccade, demonstrating that the time course of presaccadic attention can be strongly modulated by the reward associated with the movement.
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Talk Session 16 - Memory in Perception

Flexible allocation of visual selection and action planning during visual working memory

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Visual information maintained in working memory can be used to plan for and guide upcoming behavior. Yet, in daily life, the order in which visual information is encoded into working memory does not always correspond with the order in which this information will become relevant for behavior: visual information that is encoded early might only become relevant for behavior later, and vice versa. We asked how the dynamics of visual selection and planning for prospective memory-guided behavior depend on the order in which visual information is anticipated to become relevant for behavior. To address this, we developed a visual-motor working-memory task in which participants were asked to sequentially encode and memorize two colored tilted bars, that were reproduced consecutively following two separate response cues. The order in which the items needed to be reproduced could always be anticipated by the participant, and varied between trials: the cueing-order could either be the same as the encoding-order (first item cued for report first), or be reversed (first item cued for report second). We used EEG time-frequency analyses to track the selection of visual information (item location) and action planning (prospective response hand, linked to item tilt) during working memory. We show that visual selection of both items is largely unaffected by the order in which they are expected to become relevant for behavior. In contrast, signatures of action planning exhibit a clear prioritization of the action that will become relevant for behavior first. Furthermore, they show how planning to act on one memory item can take place alongside visual encoding of another item. These results reveal that visual encoding and planning for prospective manual actions can be decoupled, whereby the brain can flexibly encode new visual information into working memory, while concurrently planning to guide behavior using previously encoded visual information.

Recall requirements drastically modulate working memory representations in human visual cortex

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Visual working memory allows for temporary storage of relevant information to support adaptive behavior. Prior fMRI studies have decoded mnemonic information from activity patterns in early visual cortex (EVC) during storage. More recently, incidental high decoding of mnemonic information was found during recall using a method-of-adjustment paradigm. Given that mnemonic information is ultimately used to accomplish specific tasks, what recall requirements could invoke such EVC involvement? We manipulated recall requirements for an orientation memory task to investigate how adaptive behavior impacts EVC representations. Specifically, we used four recall conditions to dissociate the roles of visual input, motor output, and attentional monitoring. Participants reported remembered orientation (1) using button presses to rotate a thin dial on the screen via “method-of-adjustment”, (2) by viewing a “matched replay” of a pre-recorded response and indicating a clockwise or counter-clockwise offset of the final dial orientation, (3) by viewing a “mismatched replay”, i.e. a pre-recorded response to a random orientation, and pressing a button if and when the dial crossed the remembered orientation, and (4) using button presses to rotate an “invisible dial” with an initial orientation shown only briefly before response onset. We uncovered a drastic increase in memory decoding during recall when the remembered orientation matched the final dial orientation (“method-of-adjustment” and “matched-replay” conditions). This implies that motor output (required in the “invisible dial” condition) and attentional monitoring (required in the “mismatched replay” condition) alone cannot account for high EVC

involvement during recall. Instead, our findings suggest amplified information in EVC when mnemonic contents match sensory input during recall. A control experiment shows that memory recall requirements play a critical role, because the same sensory input (a rotating dial from the "matched replay" condition) without a memory task does not lead to high decoding during recall.

Neural mechanisms of episodic memory formation revealed by EEG frequency tagging

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Episodic memory formation entails the integration of diverse elements such as people, places, and objects. This process, known as binding, creates a unified memory trace that the brain maintains and retrieves as a coherent representation of the episode. Despite extensive research, the precise neural mechanisms underlying this binding process are still not fully understood. We hypothesized that the binding of disparate event elements into a unified representation could be reflected through the synchronization of neural oscillations at specific frequencies induced by EEG frequency tagging. Specifically, the coordination and communication between brain regions involved in binding may be captured in the interaction between distinct frequencies, manifested in the intermodulation frequency component. Frequency tagging, commonly used in perceptual research, could thus offer new insights into processes of higher-level cognitive integration. We conducted an associative memory task where participants encoded a series of events while their EEG was recorded. Each event comprised two images from different categories (places and objects), presented for 10 seconds. During encoding, the contrasts of the place and object images were modulated at distinct frequencies (6 and 7.5 Hz, respectively). Memory for all combinations of event-specific elements was subsequently tested, requiring participants to form strong associations between the elements within each event to succeed. Analysis of the steady-state visual evoked potentials during encoding indeed revealed an intermodulation component at 13.5 Hz, resulting from the sum of the two frequencies (6 + 7.5 Hz). The strength of this intermodulation component correlated with associative memory performance, being higher in participants with better memory scores. This finding indicates that the intermodulation component mirrors the element binding subserving episodic memory formation. Our study demonstrates for the first time that intermodulation during frequency tagging can reveal cognitive integration processes beyond mere perception.
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Memory for warning patterns: a specific link to neural excitation?

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What distinguishes the images we remember from those we forget? One hypothesis is that images that are easier to remember may evoke stronger activity in high-level vision. However, our understanding of low-level visual mechanisms that may make images memorable is limited. An intriguing case study comes from hazardous animals that adapt their appearance to be easily remembered and avoided by predators. We have previously shown that the striking arrays of stripes/spots ('warning patterns') that butterflies display evoke stronger activity in a computational model of low-level avian vision. Here, we investigated human memory for butterflies selected according to the magnitude and sparseness of the responses they evoke in modelled luminance and colour neurons. Observers (N = 50) rated on a 10-point scale their subjective perception of how memorable each butterfly appeared. They were later shown each image again and reported whether they recognised it. Butterflies that evoked stronger activity in the avian model were rated as subjectively more memorable by humans ($t = 8.75$, $p < .001$), although they were not more easily recognised later ($t = 0.36$, $p = .72$). Next, we extracted representations of butterflies from object classification deep neural networks (AlexNet, VGG-16 and 19) which are successfully used in computer vision models for predicting memorability, and examined the correspondence between activation patterns and human performance. Butterflies that contain warning patterns evoked generally stronger activations throughout networks, and the magnitude and sparseness of the activations was predictive of human memorability scores and subjective ratings. Other images (textures, natural scenes) that evoked stronger responses in the avian model also increased network activations. Our findings indicate that certain animal patterns might exploit visual processes that influence whether pictures are remembered or forgotten. This suggests that computations that underlie memorability might not occur exclusively in the late stages of human visual processing.
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Long-term memory flexibly supports visual working memory during natural behaviour

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Working memory (WM) and long-term memory (LTM) support ongoing behaviour. Their properties, as well as interrelations, have been studied thoroughly in highly controlled laboratory settings. However, little is known about how LTM and WM interact during free-flowing natural behaviour when reliance on memory emerges as a natural consequence of interacting with the environment. Critically, in these scenarios, participants can flexibly self-determine how much to rely on memory and how to coordinate this with encoding information from the external environment. In three virtual reality (VR) experiments, we embraced the flexibility inherent in naturally engaged memory. Participants copied a model display by selecting realistic objects from a resource pool and placing them into a workspace. We tracked head, hand, and eye movements as well as interactions with the environment. On this basis, we were able to index both encoding and memory usage during continuous temporally extended behaviour. Through the repetition of specific arrangements within the environment and using non-repeated/novel arrangements as a baseline, we then demonstrate how LTM contributes to the interconnected processes of encoding and memory use. Overall, we uncover multiple ways in which LTM supports naturally unfolding behaviour. First, we demonstrate that reliance on information in memory increased when arrangements were repeated compared to gathering information from the external environment. Second, in repeated arrangements, relevant information had to be sampled less often and for a shorter duration. Third, in some cases, information could be used directly from LTM, as participants did not look at the

to-be-copied objects. We also found high performance for repeated arrangements in a subsequent memory test, suggesting that the incidentally formed representations during the task were durable and accessible. Our work provides an innovative framework for investigating naturally unfolding memory-guided behaviour, offering new insight into the interplay of vision, memory, and action.
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Shifting Reliance between the Internal and External World: A Meta-Analysis on Visual-Working Memory Use

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Visual working memory (VWM) is a fundamental cognitive capacity that allows us to temporarily hold visual information, but storage is effortful and content-fragile. Rather than loading VWM to the maximum, individuals usually rely on the external world and access information just in time. However, participants do rely on VWM more as access costs to external information increase. This phenomenon is commonly investigated with so-called copy tasks, that differ across paradigms, manipulations, and dependent variables. We here present findings of a meta-analysis into the reliability and consistency of shifts in the assumed trade-off between storing and sampling across manipulations and dependent variables, using data from 28 experiments. With this work, we seek to help establish standards and comparability across this growing body of work. We found that all cost manipulations led to substantial shifts from external sampling to storage in VWM. Cost manipulations did not differ in their effect across studies even though such differences are reported within studies. All dependent variables were associated with clear but different strong effects. We argue that the differences observed between indicators are not only due to sensitivity differences but also due to differential aspects of behavior that are measured. New variables and techniques might now pave the way to understanding the trade-off between storing and sampling more in-depth. Collectively, our findings suggest that the reliance on VWM or the external world shifts consistently as access cost is increased, is largely irrespective of cost manipulations, and expresses itself reliably across dependent variables.
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Talk Session 17 - Multisensory Processing

Tactile intensity modulates visuotactile time estimates in a non-optimal fashion

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The perceived duration of objects is affected by many of their features such as size, color, or speed. Previous research has primarily focused on the timing of unisensory stimuli, although real-life objects typically possess multisensory features. Here, we investigated whether and how unisensory intensity influences multisensory time estimates. We measured and modeled visuotactile timing in two experiments. In both experiments, participants judged the duration of multisensory stimuli comprising a Gaussian blob and a collocated simultaneous tactile vibration using a temporal bisection task. In the temporal bisection task, participants first learned the shortest (1500 ms) and longest (2700 ms) durations with the baseline amplitude (4.09 m/s²). Then, they categorized seven equally spaced visuotactile durations ranging from 1500 to 2700 ms by being more similar to the shortest or longest durations. To test if altering tactile cues modulate visuotactile time estimates, we manipulated the amplitude of the visuotactile stimuli between 0.82 and 7.35 m/s2. We found that the points of subjective equality (PSEs) were lower with higher vibration amplitude, indicating that higher tactile intensity expanded visuotactile time estimates without affecting the timing precision (Weber fractions). To investigate the underlying mechanism, we conducted Experiment 2, where participants performed the same task for judging the durations of visual-only, tactile-only, or visuotactile stimuli at two levels of tactile vibration amplitude (2.45, 5.42 m/s²). Higher vibration amplitude expanded the timing of both tactile and visuotactile stimuli, replicating the results of Experiment 1. More importantly, we modeled visuotactile time estimates from visual and tactile only judgments assuming either unisensory dominance or optimal integration. Modeling results suggest that unisensory tactile estimates better captured amplitude modulation of visuotactile timing. We conclude that unisensory intensity properties modulate visuotactile timing in a non-optimal fashion and visuotactile timing might be better characterized by sensory dominance accounts.
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The development of a validated video database to investigate multi-sensory processing in misophonia and misokinesia

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Misophonia and misokinesia are characterised by a decreased emotional tolerance to specific sounds or visual movements (e.g., the sound or sight of someone slurping soup), which can trigger strong negative affective responses to those events. Previous studies focused on each sensory modality separately. They do not consider the co-occurrence of auditory and visual information in the real world, partly due to a lack of a good stimulus set. This study aims to create a publicly available video database to investigate multi-sensory processing in misophonia and misokinesia. We filmed four actors in the lab performing activities categorised as either "trigger" (e.g., eating, tapping, rustling) or "neutral" (e.g., stacking books) events. The recordings were edited to create a database of 251 videos (6-60 sec in duration). We used the Sussex Misophonia Scale and a visual version of that scale to measure misophonia and misokinesia. Participants (n=94) were assigned to groups based on their misophonia and misokinesia scores, resulting in three groups: control (n=23), misophonia-only (n=35) and misophonia-misokinesia (n=36). No participants were categorised as misokinesia-only. Participants in the three groups then rated 83-84 videos on the arousal, valence and dominance scales to measure affective responses to trigger and neutral events. We found that the control group gave lower arousal ratings to trigger events compared to the misophonia and misophonia-misokinesia groups,

and the misophonia-misokinesia group gave higher arousal ratings than the misophonia group. Additionally, the control group gave higher valence ratings (more pleasant) and higher dominance ratings (more in control of the situation) compared to the other two groups. Our database can be used to investigate the role of auditory-only, visual-only and auditory-visual information in misophonia and/or misokinesia, which may provide strategies to mitigate the negative impact of trigger events in the natural environment for people with these conditions.

Audiovisual temporal recalibration reflects both causal inference and differing auditory and visual temporal precision

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Cross-modal recalibration promotes perceptual accuracy by correcting for a systematic discrepancy between multisensory cues. Audiovisual temporal recalibration corrects for systematic lags resulting from differing physical or neural latencies between auditory and visual signals. The experience of a consistent temporal offset between visual and auditory stimuli leads to a recalibration, changing the point of subjective simultaneity so as to reduce the perceived audiovisual temporal discrepancy for these consistently discrepant signals. However, recalibration plateaus and can even be reduced for large experienced temporal discrepancy. Also, the amount of recalibration differs in response to experienced auditory lead and equivalent lag. A simple adaptation process that corrects for measured discrepancy cannot explain these findings. Here, we ask whether these phenomena result from two additional elements: (1) the observer performs causal inference, determining the probability that the sound and visual stimulus derive from the same source and should be integrated, or come from separate sources and should not, and (2) there is an asymmetry due to a difference between the precision of auditory and visual measurements of stimulus onset time. We used a typical 3-phase recalibration design. In the middle adaptation phase, participants experienced a series of stimuli with a fixed audiovisual temporal discrepancy (varied across sessions/days) and performed a task unrelated to temporal lead/lag. In the phases before and after the adaptation phase, participants performed a temporal-order judgment for stimuli with varying stimulus-onset asynchrony. We compared models with and without a causal-inference component, and models for which temporal uncertainty was either identical for the two modalities or could differ. The combination of causal inference and differing temporal uncertainty is required to explain both the diminution of recalibration gain with increasing audiovisual temporal discrepancy and the asymmetry of recalibration in response to audio lead vs. Lag.
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Perception of temporal synchrony not a prerequisite for multisensory integration

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One of the most extensively studied constructs in multisensory research is the temporal window of integration. This window is sometimes estimated by measuring the temporal boundaries within which stimuli in different modalities are perceived as simultaneous and at other times by measuring the temporal boundaries within which stimuli in different modalities render multisensory integration effects. However, recent research challenges the assumption that these approaches capture the same underlying construct. With a novel design measuring susceptibility to the most common audiovisual illusion (the McGurk/MacDonald effect) and simultaneity judgments with the same stimuli among 101 adults, we found that participants often experienced the illusion despite not perceiving the stimuli as synchronous. Additionally, the very phonetic audiovisual incongruence that produced the illusion also led to significant interference in simultaneity judgments. These findings undermine the longstanding assumption that perception of synchrony is a prerequisite to multisensory integration, support a more flexible view of multisensory integration, and suggest a complex, reciprocal relationship between temporal and multisensory processing. They also underline the importance of distinguishing the window in which multisensory integration occurs from that in which synchrony is perceived. The conflation of these measurably distinct constructs has led to considerable confusion in fundamental research that has started to extend to other domains from clinical neuropsychology to industrial applications.
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Age, Not Autism, Influences Multisensory Integration of Speech Stimuli among Adults

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Vision (in the form of lip-reading) can greatly enhance our ability to understand speech. However, among autistic individuals, imprecise and inflexible representations of the temporal relationships between sights and sounds are theorized to underlie difficulties in integrating relevant sensory information. These, in turn, are thought to contribute to problems with speech perception and higher level social behaviour. However, the literature establishing this connection often involves limited sample sizes and focuses almost entirely on children. To determine whether these differences persist into adulthood, we compared 496 autistic and 373 non-autistic adults (aged 17 to 75 years). Participants completed an online version of the McGurk/MacDonald paradigm, a multisensory illusion indicative of the ability to integrate audiovisual speech stimuli. Audiovisual asynchrony was manipulated, and participants responded both to the syllable they perceived (revealing their susceptibility to the illusion) and to whether or not the audio and video were synchronized (allowing insight into temporal processing). In contrast with prior research with smaller, younger samples, we detected no evidence of impaired temporal or multisensory processing in autistic adults. Instead, we found that in both groups, multisensory integration correlated strongly with age, and participants were able to adapt to differing degrees of asynchrony from trial to trial in a process called rapid temporal recalibration. This contradicts prior presumptions that differences in multisensory perception persist and even increase in magnitude over the lifespan of autistic individuals. It also suggests that the compensatory role multisensory integration may play as the individual senses decline with age is intact. These findings challenge existing theories and provide an optimistic perspective on autistic development. They also underline the importance of expanding autism research to better reflect the age range of the autistic population as well as the role that vision can play in enhancing speech perception, particularly as hearing declines with age.
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Multisensory degradation in speech perception reveals the processing of scalar implicatures

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Language comprehension is a multisensory process that involves the readout of visual and auditory information to understand complex stimuli such as words and what these imply. An open debate regards the processing of scalar implicature, i.e. pragmatic inferences that enrich the meaning of an utterance (e.g. in a sentence like “a few of the goats moved in the enclosure”, “a few” could be literally interpreted as “a few and possibly all of them”; or with a pragmatic interpretation as a subset of the total set: “a few but not all of them”). By focusing on multisensory processing in speech perception, we test whether a degraded multisensory signal affects the computation of scalar implicatures. On each trial of a 2AFC task, we present participants with two scenarios where either a few-but-not-all, all or none of cartoon-like animals move from one place to another, then a video appears displaying a speaker’s face uttering the command sentences which includes the target quantifier; once the video disappears, participants choose the scenario that represents the uttered sentence. Responses are registered by recording eye movements in this last phase. We manipulate the ambiguity of the scenarios and the sensory certainty of the uttered quantifier. In the ambiguous condition, we present one scenario showing “only a few”, the other showing all the relevant elements moving and an uttered sentence such as “look where a few of the dogs moved to the field”. In this condition, under multisensory degradation, we observe a lower proportion of looks towards the subset of elements moving. In other words, sensory uncertainty caused a reduction of scalar implicature computation, required to process as false the interpretation that “all” elements moved. Such selective susceptibility to sensory uncertainty suggests that pragmatic inferences are derived through an interpretation of quantifiers that depends on speaker’s intention recognition.