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PERCEPTION

Perception
2022, Vol. 51(1S) 1–207
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The 44th European Conference on Visual Perception (ECVP) 2022, Nijmegen, The Netherlands

The ECVP is a yearly European Conference in which researchers from all parts of the world convene. As its name implies, the conference centers around visual perception research and fields that connect to visual perception such as multisensory processing, attention, decision making, artificial intelligence, aesthetics etc. The overall goal of the meeting is to provide a forum for presentation and discussion of new developments in our understanding of human, animal and machine vision. Empirical, theoretical and applied perspectives are all encouraged.

The ECVP is a unique and lively conference, which travels through Europe and mostly takes place in a European university city, organized by a local team. Due to the Covid pandemic the edition of 2020 was skipped and in 2021 the conference was held online. See https://ecvp.eu for an overview of all past ECVP locations. In 2019, we pitched the Nijmegen proposal at the ECVP in Leuven, but we decided to really push forward just about a year ago (August 2021). We were really happy that we could organize an in-person meeting in 2022. So, that also our youngest colleagues could taste the pleasure and benefits of being together under one roof.

Planning a conference like this while the virus was still very much around was only possible because we could move almost completely to the Radboud University campus. We decided that the presentations (talks and posters) were, in principle, to be given on site in Nijmegen, but we also opened up science and intensified discussion, also for those who could not be in Nijmegen, by online postings during the conference (by using 'Slack') and by posting recordings of the lectures (made available at a later moment). We had approximately 650 participants from 43 countries. Over 5 days, we had a line-up of 3 keynotes, 6 tutorials, 26 talk sessions, 14 symposia, more than 300 posters, and a social program (like a welcome reception; an open 'illusion and demo' night, a conference dinner, a farewell party etc.). In addition, we had a grant-program to stimulate young scientists who were not able to travel because of financial reasons, special green travel grants, daily poster prizes and some extras like vegetarian lunches and a BBQ for all, and the choice between a university bicycle or a 5-day Nijmegen-area bus ticket. Of course, the core business of the ECVP is vision science, but we felt that especially this year, being able to socialize and to create time and space to meet up with our fellow scientists after so long was a big surplus.

As organisers we are thankful for the helpful cooperation of the Radboud University and the Donders Institute in getting things done. Organising is team work and we were able to built a team of enthusiastic staff members; the 'ECVP22 team'. Beside the ECVP22 team there were many other people who helped us out. We would like to thank people from the university catering, the media technique, the doormen, the cleaning team etc. We are also thankful to all our volunteer students, and we thank our sponsors who supported this event in a financial way. Last but certainly not least we got lots of help from colleagues in the field and participants by taking up various roles: as a reviewer, a symposium organizer, a tutorial teacher, or accepting a role as chair, or simply by sending in all abstracts (and paying the fees). As we all know, the presentations are the building blocks of a good scientific conference. It is all about communication, about exchange, connectedness. We will always remember the mere pleasure (and, yes, some stress ;-)) we had in organizing this event with our great team, but even more so we remember the pleasure that we noticed among participants in a vibrant, creative, fantastic and wonderful atmosphere. Thank you all!

Rob van Lier,
on behalf of the ECVP'22 team

ECVP'22 team

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More Information @ https://2022.ecvp.eu
In this ECVP supplement you find all abstracts of authors who gave their consent to publish their abstract.

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Keynote lectures

ECVP 22 abstracts

Keynotes

Keynote 1. The Perception Lecture (28 August 2022)

Gestalts in Vision

Johan Wagemans[1]
[1]KU Leuven

The notion of a "Gestalt" refers to all kinds of structured organizations occurring in our perception of the world around us. Although Gestalt psychology as a school of thought is considered dead by most scholars in vision science, Gestalts are still pervasive in our visual experience. There are many types of Gestalts, occurring at many levels in the cortical hierarchy and across many timescales, from a single glance to extended looking. For instance, think about classic cases of perceptual grouping, figure-ground organization, perceptual multi-stability, the role of emergent properties and contextual effects, the role of anchor points and reference frames in shape and motion perception, configural face perception, biological motion perception, spatial relations in scene perception, part-whole relationships, unity and variety in design, good composition in art, and so forth. In this Perception Lecture, I will discuss some common misunderstandings regarding the Gestalt approach to this rich set of phenomena. I will argue that Gestalts should be considered as the key players in vision, mediating a two-way connection between lower-order stimuli and higher-order percepts, and between activity in low-level neurons and high-level cortical areas. I will suggest that the integration of Gestalt thinking into mainstream vision science is complicated by implicit assumptions about linear systems in psychophysics and visual neuroscience, and by a lack of respect for phenomenology. Throughout the talk, I will clarify the misunderstandings as well as the recent advances regarding Gestalts in vision by describing a few lines of research from our lab. This lecture will hopefully demonstrate that a nuanced, non-mainstream view on Gestalts can still teach us much about perception.

Keynote 2. The Vista Lecture (29 August 2022)

How AI can advance research in visual perception

Marcel van Gerven[1]
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Artificial intelligence (AI) has made significant progress over the last decade, moving from solving toy problems towards solving challenging real-world problems. Also in the domain of visual perception, AI holds several promises. AI models are capable of generating ever-more realistic visual stimuli, can be used to model visual information processing and even allow for the readout and control of visual percepts. In this talk, I will discuss some of the recent progress in these areas and reflect on how AI can accelerate scientific and engineering breakthroughs in the domain of visual perception.

Keynote 3. The Rank Lecture (31 August 2022)

Plastic Brains for flexible decisions

Zoe Kourtzi[1]
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Artificial intelligence (AI) has made significant progress over the last decade, moving from solving toy problems towards solving challenging real-world problems. Also in the domain of visual perception, AI holds several promises. AI models are capable of generating ever-more realistic visual stimuli, can be used to model visual information processing and even allow for the readout and control of visual percepts. In this talk, I will discuss some of the recent progress in these areas and reflect on how AI can accelerate scientific and engineering breakthroughs in the domain of visual perception.

29 August 2022

Symposium 1. Computational perspectives on perceptual confidence

Reported confidence reflects representation of Bayesian probability in human visual cortex

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It is well known that humans are often remarkably good at evaluating the quality of their perceptual decisions – a metacognitive skill called 'confidence'. The neural computations underlying such judgments of confidence, however, remain poorly understood. Recent Bayesian theories propose that confidence is based on a representation of probability and uncertainty in cortex. We tested this hypothesis using a combination of computational modeling, psychophysics and fMRI.

Participants viewed noise-free gratings of random orientation (0-179 degrees) and reported both the orientation and their level of confidence in this perceptual judgment. Using a generative model-based analysis technique (van Bergen, Ma, Pratte & Jehee, 2015), we decoded probability distributions from activity in visual cortex (V1, V2, and V3, combined). The width of the decoded distribution was taken as a measure of the degree of uncertainty in the cortical stimulus representation. The human data was compared to simulated data from a Bayesian observer, as well as two alternative models implementing heuristic strategies to confidence. We discovered that human confidence judgments reflect the degree of uncertainty in the cortical representation. More specifically, observers reported higher levels of confidence when the decoded probability distribution was narrower, as predicted by the Bayesian model. We furthermore found that activity in the insular, anterior cingulate, and prefrontal cortex was linked to both decoded sensory uncertainty and reported confidence, in ways predicted by the Bayesian model. Taken together, these findings support Bayesian theories of confidence and suggest that subjective confidence is based on a probabilistic representation of uncertainty in cortex.

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Effects of prior information on subjective confidence

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Literature on Bayesian inference assumes our perception to depend on integrating prior expectations ("priors") and incoming information to form the posterior belief or percept. This posterior is then thought to inform both our perceptual decisions and our decision confidence. However, this assumes confidence to be based on the optimal integration of priors and incoming sensory evidence, yet it remains unclear how confidence judgments weigh these different sources of information. In order to make quantitative predictions about confidence across different situations and rigorously test confidence models, it is critical to understand how priors are integrated. We aimed at quantitatively assessing how priors are used in confidence, compared to their use in decisions. In a gamified dual-decision task, we varied the precision of priors ('cue' stimuli) and new sensory evidence ('target' stimuli) to create pairs of conditions that were matched on posterior precision level, but differed on whether the cue or the target was the more informative stimulus. We found that prior information was underweighted in discrimination decisions. In contrast, confidence judgments used the priors to a greater extent, with the priors and incoming evidence weighted evenly following correct decisions, and with the priors overweighted following incorrect decisions. These results were further supported by fitting a Bayesian model with a weighting parameter for the prior information at both the decision and confidence level. Together, these findings revealed that prior information can be accessed and more optimally used in explicit, subjective confidence, even when it is dismissed in decisions.

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Bayesian confidence in optimal decisions

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The optimal way to make decisions in many circumstances is to track the difference in evidence collected in favour of the options. The drift diffusion model implements this approach and provides an excellent account of decisions and response times. However, the DDM struggles to account for confidence reports, because responses are triggered when the difference in evidence reaches a set value, suggesting confidence in all decisions should be equal. Many theories of confidence have therefore used alternative, non-optimal models of decisions. Motivated by the historical success of the DDM, we consider simple extensions to this framework that might allow it to account for confidence. Motivated by the idea that the brain will not duplicate representations of evidence, in all model variants decisions and confidence are based on the same evidence accumulation process. We compare the models to benchmark results, and successfully apply 4 qualitative tests concerning the relationships between confidence, evidence, and time, in a new preregistered study. Using computationally cheap expressions to model confidence on a trial-by-trial basis, we find that a subset of model variants also provide an excellent account of the precise quantitative effects observed in confidence data. Specifically, our results favour the hypothesis that confidence reflects the strength of accumulated evidence penalised by the time taken to reach the decision (Bayesian readout), with the penalty applied not perfectly calibrated to the specific task context. More generally, these results support the idea that confidence and decisions may be based on the same drift diffusion evidence accumulation.

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A low-dimensional approximation of optimal confidence

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When making a decision, we usually experience a sense of confidence. According to Bayesian decision theories, confidence reflects the learned probability of making a correct response, given a certain amount of accumulated evidence and response time. Although optimal, independently learning this probability for each point in the evidence X time space would be computationally intractable. In this talk, I will describe a novel model of confidence implementing a low-dimensional approximation of this optimal yet intractable solution. I will provide empirical evidence that this model (1) can accurately fit both choice (accuracy, response time) and confidence behavior simultaneously and (2) can capture experimentally-induced confidence biases. Finally, I will discuss how this model can be extended to trial-by-trial learning of accurate confidence judgments.

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A generative model for visual confidence judgments

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Visual confidence is an evaluation of the validity of our visual decisions. Inspired by Signal Detection Theory that considers that all perceptual decisions are based on some sensory evidence, we present here a complete generative model that describes how confidence judgments result from some confidence evidence. The quality of the confidence evidence determines confidence sensitivity, namely the ability to distinguish subtle differences in our own performance. Confidence sensitivity is affected by the two main parameters of the model, confidence noise and confidence boost. While confidence noise reduces the reliability of the confidence evidence, confidence boost helps confidence judgments by injecting novel information other than that used during the perceptual decision. The opposite effect of these two parameters creates a problem of confidence parameters indeterminacy, where the confidence in a perceptual decision is the same in spite of differences in confidence noise and confidence boost. We discuss experimental conditions that let us estimate both of these parameters, thus giving us the opportunity to decide whether confidence is generated using the same primary information that was used for the perceptual decision or some secondary information. We also describe a novel measure of confidence efficiency relative to the ideal confidence observer, as well as the estimate of one type of confidence bias. Finally, we apply the model to the confidence forced-choice paradigm and the more classical confidence rating paradigm.

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Symposium 2. Visual expertise: real-life applications and underlying mechanisms

Human expertise for face identity processing - insights from Super-Recognizers

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Numerous scientists have considered face processing "the ultimate domain of visual expertise" (Harel, 2016). From a nature-nurture perspective, face processing represents an interesting field of research: On the one hand, experience enhances proficiency (e.g. Ramon & Gobbini, 2017; Ramon et al., 2015), while on the other hand ability is to a large degree genetically determined (Wilmer, 2017). In this talk, I will focus on so-called "Super-Recognizers" (Russell et al., 2009; Ramon, 2021). Super-Recognizers - whose skill is neither acquired nor trainable - can be considered the "experts among experts" of face identity processing. After a brief synthesis of the status quo in SR research, I will present recent behavioral and neuroimaging findings. The talk concludes with an outlook into ongoing applied work in policing contexts, which highlights the value of fundamental research into on Super-Recognizers' unique, innate skill.

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Visual Expertise in Medical Image Perception

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Cancer screening saves lives. In recognition of this fact, screening programs in breast, cervical and lung cancer are performed by medical image experts who look for signs of cancer in difficult, time-consuming visual search tasks. Medical image interpretation requires radiologists to engage in perceptual and analytical processes to make decisions about diagnosis and treatment. Radiological images can be thought of as a specialized class of scenes and radiologists are experts who have learned to apply the processes of visual cognition to these unusual scenes. Building on recent advances in basic research on vision and attention, we have found a "global gist signal" in radiographs afforded to expects after an initial glimpse and containing information about

the presence of disease that is independent of the locus of any lesion. The global gist signal carrying the global structure and statistics could be used to improve the speed and/or accuracy of breast cancer screening. I will address the nature of this signal and what allows medical image experts to detect it, how this expertise can be trained as well as ways to refine screening protocols and inform and enhance the capabilities of computer-based detection systems.

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Visual expertise is not due to the lack of temporal biases in radiologists and super-recognizers

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Individuals with visual expertise possess superior skills when executing visual tasks. Visual expertise ranges across several domains, such as radiology, ornithology, and visual expertise with faces is the key feature which defines super-recognizers. Despite extensive research on the topic, the mechanism(s) underlying these superior visual skills remain(s) unclear. A key recent finding is that our perception is continuously biased towards the past (i.e., serial dependence). This constant visual error is proposed as a mechanism that promotes perceptual stability in everyday life. Here, we hypothesized that an absence of this constant source of error could account for enhanced performance in visual expertise. To this end, we tested whether serial dependence impacts radiologists' recognition of simulated lesions embedded in radiographs. We found that serial dependence affected radiologists' recognition; on average, perception was pulled 13% toward the previous stimulus. Crucially, serial dependence strength was similar in radiologists and untrained observers. Along the same lines, we tested whether serial dependence impacts super-recognizers' performance for identity and shape recognition. We tested a group of super-recognizers, and compared the strength of serial dependence to an age-matched control group. We found serial dependence in controls and super-recognizers alike. This body of results shows that the superior visual skills in radiologists and super-recognizers cannot be attributed to a lack of temporal biases. These results instead further reinforce the idea of serial dependence as a pervasive, general mechanism exhibited by various populations. Avenues to mitigate this source of error will be discussed.

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The refinement of domain-specific neural representations through expertise

Hans Op de Beeck[1]
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The human brain contains a complex information processing system that underlies the extraordinary ability of humans to quickly and flexibly extract meaning from incoming visual input. This system is further finetuned when individuals obtain domain-specific expertise. Many brain imaging studies have investigated the extent to which this fine tuning invokes domain-specific brain regions, yet no overall consensus has been reached. I will propose that the fine tuning involves a mix of domain-specific and domain-general processes. A much more interesting yet less investigated question pertains to how the representations of within-domain knowledge in the implicated brain regions are affected and enriched by the acquisition of expertise. This a challenging inquiry because it requires the detailed measurement of within-domain selectivity, which is typically associated with a poor signal to noise in noninvasive brain imaging even with the use of multivariate methods. I will describe attempts to obtain such measurements and how the findings reveal that expertise transforms the representational geometry of within-domain knowledge.

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Neural correlates of mnemonic expertise

Martin Dresler[1]
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Memory skills differ considerably across the general population – from age-related memory loss to the outstanding feats of memory champions. Memory research focuses largely on normal or impaired memory, whereas little is known about the cognitive and neurobiological basis of exceptional memory skills. I will present insights from a series of studies on the world's leading memory champions, and naïve subjects undergoing mnemonic training. Our studies suggest that the outstanding skills of memory champions rely on mnemonic strategies that translate abstract information into visual representations. Such visualization strategies allow for more efficient neural coding, and a direct access to long-term memory structures also during classical working memory tasks. Moreover, training in these strategies drives regional brain activation, neural representations and network connectivity also in normal individuals towards the neural patterns observed in memory champions.

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Visual expertise across the primate order and the role of the ventral visual cortex

Jessica Taubert[1]
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The overarching goal of my research is to understand how we quickly and accurately recognize different facial attributes. Our remarkable ability to "read the room" is a form of visual expertise that we share with other primates, yet its neural basis is only partially understood. Further different aspects of this expertise, including how we recognize facial expressions and members of the same genetic family, remain understudied. In this talk I will first describe some of gaps in our knowledge and then demonstrate how we can combine behavioural experiments with functional brain activity and single unit recordings to get a better understanding of how neural mechanisms in the ventral visual cortex extract socially-relevant cues from naturalistic face stimuli. More specifically, I will talk about recently collected data that speak to (1) the role of the ventral visual cortex in face detection (2) the sensitivity of the ventral visual cortex to emotional tags and (3) whether kin recognition is a unique form of visual expertise. These data set the stage for future studies that will identify the neural circuits responsible for reading faces and guiding social behavior in both human and nonhuman primates.

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Symposium 3. Large-scale spatial vision

What determines perception of an element?

Michael Herzog[1]
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Classically, the perception of a visual target is explained by small local circuits, which sample information from a narrow region around the target. For example, in visual crowding it was proposed that flankers can interfere with the target only when they are presented within Bouma's window. Here, we first show that the perception of an element in the visual field depends on almost all other elements in the visual field as well as their specific configuration. Further, we show that the perception of such an element does not only depend on the large-scale spatial but also temporal context within a window of up to half a second. We argue that processing such large-scale spatio-temporal information is necessary to solve the ill-posed problems of vision and to establish perceptual identity across space and time. Further, we show that these observations can be modeled by the concatenation of small visual circuits when allowing for time-consuming computations.

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Visual symmetry perception, across space and time

Marco Bertamini[1], **Alexis Makin**[1], **Giulia Rampone**[1]
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Image segmentation, i.e., parsing foreground from background, and grouping, i.e., combining local information into wholes, are fundamental to visual perception. In both cases local as well as global information is relevant. A well-known case of global influence is that of symmetry, already described by Gestalt psychology. Symmetry exists as a non-local match of features, and performance is extremely good even for sparse patterns that span several degrees. Studies have found a response to symmetry in extrastriate areas. For example, symmetry produces an ERP component known as Sustained Posterior Negativity (SPN). Different techniques provide converging evidence that the response is automatic: these areas always respond to symmetry in the image (Bertamini et al. 2018; Sasaki et al., 2005, Keefe et al., 2018). However, the response is selectively enhanced when symmetry is task relevant. The strength of the activation varies with type of symmetry (reflection is most salient) but the network is the same. Location of a pattern in central vision is not critical: Automatic contralateral responses are present with stimuli 3.2 degrees from fixation (Wright et al., 2017). Finally, the same areas are activated when the observer finds symmetry by comparing parts of an object over time (Rampone et al., 2021). Overall, symmetry provides a special case of structure that the visual system extracts globally, automatically, and across the image, and in some cases, it can be extracted even when symmetry is not present in the image, requiring an integration over space and time.

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Apparent motion as a model for predictive feedback mediating long-range spatial integration

Petra Vetter[1]
[1]University of Fribourg

Long-range apparent motion is a model to study how local flashing stimuli are integrated into an illusory motion percept spanning a comparatively large part of the visual

field. Evidence from psychophysics, neuroimaging and brain stimulation suggests that the long-range spatial integration during apparent motion is mediated by predictive feedback signals from motion area V5/MT to primary visual cortex V1. I will present evidence from several experiments demonstrating how these predictive feedback signals affect both neural activity in V1 and visual target detection on the apparent motion path, and how these feedback signals are transferred across saccadic eye movements. This evidence demonstrates that a spatio-temporally specific prediction about the time and location of an illusory motion token is created in V5 and sent down to V1, mediating the spatio-temporal integration of the inducing flash stimuli as well as creating the perception of long-range apparent motion. Taken together, this evidence provides support for predictive feedback as a potential neural mechanism for visual context integration across relatively large spatial scales.

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The relationship between image-computable features and objecthood

Christoph Teufel[1]
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Extraction and processing of low-level features is typically thought to be carried out by local visual mechanisms in early retinotopic cortex. Conventional models of object recognition suggest that pooling of outputs of local mechanisms generates selectivity to increasingly complex and larger features along successive stages of visual processing, ultimately resulting in representations of object-parts and whole objects. Here, I will reconsider this bottom-up model of object perception, focussing on the relationship between image-computable features and object representations. I will discuss studies showing that processing in local mechanisms is modulated by objecthood, where the latter is not sufficiently specified by features but requires prior object-knowledge to emerge. Specifically, once bound into a global object representation, processing of local elements consistent with the high-level percept is sharpened. A separate set of studies shows that this modulation is determined by the extent to which the class of features that the local element comes from is relevant to the object representation. The findings suggest that large-scale perceptual organisation processes, required for the emergence of object representations, flexibly modulate processing of low-level features by local mechanisms. Overall, I argue for a reassessment of our conceptualisation of the relationship between image-computable features and objecthood.

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Slow active representation of global scene layout impacts fast automatic reconstruction of local image structure

Peter Neri[1]
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Perceptual analysis of visual signals is typically modelled via local circuits resembling cortical neurons. These circuits are impacted by their wider context, such as the highly structured nature of environmental signals; existing measurements, however, are primarily restricted to constrained viewing conditions where human observers cannot display the full repertoire of natural vision. We overcome this limitation by performing quantitative measurements of visual discrimination in virtual reality.

Participants operated within a virtual room containing numerous edges that were either 'image-based' or 'object-based': for example, a high-contrast edge lining the wallpaper is image-based but not object-based; conversely, the boundary between a box and its background may carry no image-based contrast, but would mark an object-based edge. We locally perturbed edge regions and required observers to discriminate their orientation ('sensory task'). At the same time, observers engaged in a 'memory task' that probed spatial representation of room layout. We manipulated the availability/reliability of shadow information and studied its impact on cognitive processes supporting the two tasks.

Our results demonstrate a complex interplay between these processes. When shadow information is unavailable/unreliable, observers shift their weight towards image-based cues to the detriment of object-based cues for performing the sensory task. Dynamic re-allocation of cue information happens slowly and is driven by global environmental changes, however it impacts local processes that analyze visual signals on the sub-second scale, thus providing a compelling demonstration of the integrated nature of sensory processing during natural behaviour.

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Talk session 1. Attention I

Visual lecture features and student engagement in asynchronous remote learning: the DAD Time Project

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Mandatory remote education during the pandemic suddenly required students and teachers to engage in long-

distance classes. The switch from the in-person to the remote setting implies a change in communication: Teachers faced the challenge of engaging students through a substantially new medium. The DAD Time Project aims to understand which video lecture's visual, auditory, structural, and content features can facilitate students' sustained attention. To this end, we collected data on asynchronous remote classes held by the University of Milano-Bicocca during the academic year 2020-2021. The presentation will focus on the relationship between the visual components of video lectures (i.e., signal quality, content type, visual cluttering) and users' mode of engagement that will emerge from the analyses currently underway. The data refers to 27 video lessons belonging to 17 courses and attended by 1709 students (57 - 301 students per lesson, M = 157.41, sd = 64.05). For each lecture, we identified the most and least frequently viewed sections, distinguishing between the students' first day of access and the two weeks preceding the final examination of the respective course. We are now investigating the visual features of these sections. In addition, we used cluster analysis to identify different profiles of students' content consumption, and we are examining whether these profiles are associated with the lectures' overall visual characteristics.

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The role of transient attention in crowding and feature binding

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Crowding refers to the failure to identify a peripheral object due to nearby objects (flankers). A hallmark of crowding is inner-outer asymmetry; i.e., the outer flanker (more peripheral) produces stronger interference than the inner one. Here, by manipulating attention, we tested the predictions of two competing accounts: the attentional account, which predicts a positive attentional effect on the inner-outer asymmetry (i.e., attention to the outer flanker will increase asymmetry) and the receptive field size account, which predicts a negative attentional effect. In Experiment 1, observers estimated a Gabor target orientation. A peripheral pre-cue drew attention to one of three locations: target, inner flanker or outer flanker. Probabilistic mixture modeling demonstrated asymmetry by showing that observers often misreported the outer-flanker orientation as the target. Interestingly, the outer cue led to a higher misreport rate of the outer flanker, and the inner cue led to a lower misreport rate of the outer flanker. Experiment 2 tested the effect of crowding and attention on incoherent object reports (i.e., binding errors - reporting the tilt of one presented item with the color of another item). In each trial, observers estimated both the tilt and color of the target. Attention merely increased coherent target reports, but not coherent flanker reports. The results suggest that the locus of spatial attention plays an essential role in crowding as well as inner-outer asymmetry and demonstrate that crowding and feature binding are closely related. However, our findings are inconsistent with the view that covert attention automatically binds features together.

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A dual-process model of visual perspective taking: the role of others' intention.

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Humans rapidly and effortlessly direct their attention toward a location indicated by a cue. This phenomenon can be measured with the Dot Perspective Paradigm (DPP; Samson et al., 2010), consisting of a virtual room with targets presented on its walls. A cue is placed in the centre of the room to direct attention. Participants judge as quickly as possible how many targets are visible from either their own or the cue's perspective. This task shows an interference: slower RTs and more errors when the cue is facing away from the targets. It is debated whether this interference is due to the social or the directional features of the cue. We advanced a dual-process model composed of an orientating and a decisional process (Pesimena & Soranzo, in press). The first is sensitive to the directional features of the cue and measured by RTs, whilst the latter is sensitive to its social feature – such as the intention of pointing – and measured by the errors. To test this model, we used a modified version of the DPP in which a human-shaped cue had an arm pointing either in the same or opposite direction of its face; thus, manipulating both directional features and the intentionality. Results show the usual interference when the arm pointed in the same direction as the face. However, the interference disappeared when the arm pointed in the opposite direction. This is consistent with the dual-process model, supporting the importance of intentionality in the decisional process.

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Predicting individual selection events during visual foraging

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Visual foraging is a paradigm in which participants must find multiple targets among distracters. Previous work (Kristjánsson, et al, 2014, PloS One) has shown that when search is hard participants tend to select targets in runs of one type, then another. We have recently developed a generative model that requires only four parameters yet can fully account for human behaviour at the summary statistics level (Clarke, Hunt & Hughes, 2022, PloS Comp. Bio). Here, we investigate how well the model can predict which specific target will be selected during a trial. We find that our model is on average fairly accurate, although there is considerable variation in how predictable different participants are (range: [43%-69%]; chance = 11%) and that the feature foraging is easier to predict than conjunction (67% compared to 59%). These differences appear to be driven by differences in the weighting put on proximity between different participants and conditions. Finally, in order to improve our model's predictions, we model how likely different items are to be selected as the first item in a trial. We find a bimodal distribution in which most participants start in the top left corner, but a subset favour initiating their search from the centre of the display. Overall, we find that our model does a good job of accounting for behaviour in visual foraging tasks, and we demonstrate how we can learn more about human behaviour by investigating the cases where models fail to match the empirical data.

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Multiple object tracking: effects of goal valence on allocation of attention

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When visually tracking an object through space, do you attend to the object itself, or are you always a few steps ahead? We previously found that tracking multiple objects involves anticipatory attention especially in the linear direction, even when a target bounces against a wall. We also showed that active involvement, in which the wall was replaced by a controllable paddle, did result in increased allocation of attention to the bounce direction. In the current experiments we wanted to further investigate the potential influence of the valence of an object's heading. Specifically, in Experiment 1 participants were instructed to catch targets with a movable goal (i.e., paddle). In Experiment 2, participants were instructed to manipulate the permeability of a static wall in order to let targets either approach goals (i.e., green goals) or avoid goals (i. e. red goals). In Experiment 1, probe detection ahead of a target that moved in the direction of the goal (i.e., the paddle) was higher as compared to probe detection in the direction of a no-goal area. In Experiment 2, it was found that not so much the positive (or neutral) valence (here the green and no-goal areas) led to increased allocation of attention, but rather that a negative valence (here the red goals) led to a decreased allocation of attention. We speculate that in Experiment 1 the same strategy might have led to the relatively higher probe detection rates when targets were heading toward a goal area.

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Indexing spatial attention with pupillometry: a useful tool to detect pseudoneglect in healthy controls and diagnosing cerebral visual impairments

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Pupil size changes in response to changes in focal distance, attention (orienting, alerting, and executive function), and light level. Changes associated with changes in light levels are not purely reflexive, but modulated by spatial attention. More specifically, the pupil changes as covert attention is moved to parts of the visual scene of differing brightness. I present a method to assess lateralized attention over time exploiting this phenomenon. When presented with black/white and white/black hemifields at constant fixation, healthy controls showed a stronger pupil light response to the left rather than to the right side of the display. This finding corresponds to so-called pseudoneglect, the finding that healthy participants demonstrate an on average slight leftward attentional bias. Differences in pupil responses were mainly driven by the visual periphery and correlated to the greyscales task, an established paper-and-pencil task to obtain spatial biases. The time-course of effects hereby argues for a critical involvement of the orienting response in the emergence of pseudoneglect. In ongoing work, we assessed the feasibility of this method for the diagnosis of hemispatial neglect, a frequent condition after right hemispheric brain damage in which attention to the left side of the display is reduced. Indeed, neglect patients show pupil light responses that reflect the right side of the display stronger than the left side whereas healthy controls again show a slight leftward bias in their pupil light responses. Furthermore, I present data obtained from patients with hemianopia, a visual impairment caused by brain damage in the occipital lobe.

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Talk session 2. Bistable Perception

Kinetic-depth effect multistability persists when attention is distracted by an attention-demanding RSVP task

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Does multistable perception require attention? The answer is "yes" for binocular rivalry but "probably not" for other multistable displays. We re-examined this question in two experiments using kinetic-depth effect (KDE) displays where participants viewed multiple ambiguously rotating objects (two in Experiment 1, three in Experiment 2, randomly but evenly distributed along the circle), the initial direction of rotation was randomly biased via size/distance cues. After the biasing cues were gradually removed, axes of rotation rotated from vertical to horizontal over a two-second interval and all but one object disappeared with participants reporting on its direction of rotation. Orthogonal orientation of initial and final axes of rotation ensured that initial and final direction of rotation could be correlated only if multistability persisted during axes rotation. As a control, we included a "jump" condition with rotation axes abruptly changing their orientation. In Experiment 1, we manipulated attention via validity cues with different colors indicating the probability of an object being a target (50%, 67%, 83%, 100%). Here, we found that persistence of perceptual dominance was not affected by validity cues and was immune to any difference in allocation of spatial attention. In Experiment 2 participants performed an attention-demanding RSVP task during the axes rotation interval. We found that although the persistence of perceptual dominance was weaker during the inattention condition, it was significantly higher than that for the jump condition. Taken together this indicates that the multistability of KDE persists without attention. Open data and analysis: https://osf.io/ysb4n/

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Decision making in a dish: fundamental mechanisms of bistable visual information processing in mouse visual cortical brain slices

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Visual decision mechanisms are often studied using bistable stimuli. In a bistable visual stimulus the evidence for one visual percept is similar to the evidence for the other percept. We studied the basic mechanisms how the brain decides what percept arises. In an in vitro set-up we investigated the fundamental mechanisms of bistable perception. We developed a "hybrid" system where two real-life pyramidal neurons in a mouse visual cortical brain slice interact through a computer simulated mutual inhibition circuit. Simultaneous activation of the mutually inhibiting pyramidal neurons leads to bi-stable activity. We observed that the circuit exhibits dynamics strikingly similar to the known properties (Levelt's laws) of bi-stable visual perception. Furthermore, we investigated the effect of noise in those decision processes by minimizing noise by blocking intrinsic synaptic noise with GABA and glutamate antagonists. The results under those conditions show a reduction of the number of reversal frequencies, but bistability still occurs. We conclude that basic phenomena of bistable vision can be explained with the properties of real visual cortical neurons combined with modeled inhibitory interactions.

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The effect of short-term monocular deprivation depends on the duration of deprivation: evidence from binocular rivalry and binocular combination.

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The ocular dominance (OD) shift observed after short-term monocular deprivation (MD) is a widely used measure of visual homeostatic plasticity in adult humans. Binocular rivalry and binocular combination techniques are used interchangeably to characterize homeostatic plasticity, sometimes leading to contradictory results. Here we directly compare these two techniques by investigating the impact of the MD duration on OD in adult humans.

We measured the effect of 15 minutes and 120 minutes of MD in 15 adult volunteers. OD was assessed either by binocular rivalry (BR, orthogonal gratings: size 2°x2°, SF: 2 cpd, contrast 60%) or binocular phase combination (BC, sinusoidal gratings, size: 3.5°x3.5°, SF: 1 cpd, base contrast: 50%). Each subject underwent four deprivation sessions (2 durations x 2 conditions) in separate days and in a counterbalanced order.

We found that the effect of MD exhibited a strong dependence on the deprivation duration (BR: 15min vs. 120min: $F(1,14)=36.2$ $\eta 2=0.313$, $p < 0.001$; BC: $F(1,14)=27.0$ $\eta 2=0.278$, $p<0.001$), with longer deprivation inducing a stronger and longer-lasting effect for both

techniques. Specifically, 15 minutes of MD did not induce a significant OD shift. Finally, the effect of 2h MD correlated across subjects for the two techniques (r=0.55, p=0.03).

Our results show that the effect of short-term MD strongly depends on the duration of deprivation, regardless of the technique used to measure ocular dominance. These results indicate that the effect of short-term MD builds up over time during deprivation, corroborating the evidence in favor of a cortical origin of the effect.

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Stable individual differences in hysteresis and adaptation: Evidence for differential use of stimulus history and perceptual history when perceiving multistable dot lattices

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How we perceptually organize a visual stimulus depends not only on the stimulus itself, but also on the temporal context in which the stimulus is presented as well as on the individual who is processing the stimulus and context. Earlier research found both attractive and repulsive context effects in perception: tendencies to organize visual input in a similar way as preceding context stimuli (i.e., hysteresis) co-exist with tendencies that repel the current percept from the organization that is most dominant in these contextual stimuli (i.e., adaptation). These processes have been studied mostly on a group level. In this study using multistable dot lattices as stimuli (N = 75), we implemented a Bayesian hierarchical model comparison approach to investigate whether true individual variation exists in the size of these effects, and whether everyone shows both effects in the expected direction. Furthermore, we investigated temporal stability of these individual differences across time (one to two weeks apart).

The results demonstrate that large individual differences in the size of these attractive and repulsive context effects exist. Furthermore, these individual differences are highly consistent across timepoints. Although almost everyone showed both effects in the expected direction, not every single individual did. In sum, the study reveals how individuals differ in how they combine previous input and experience with current input in their perception, and more generally, this teaches us that different individuals can perceive identical stimuli differently, even within a similar context.

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How to form perceptual memory of multistability: Bias perception but gently

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When multistable displays are presented intermittently with a long blank interval, they become stabilized via perceptual memory. However, we still lack an understanding of perceptual memory's role in daily vision, its mechanisms, and even the conditions that lead to its formation. Therefore, we used a reverse correlation method to recover a biasing sequence that forms perceptual memory. In the experiment, participants reported on the direction of rotation of intermittently presented (800 ms on, 1000 ms off) kinetic-depth effect displays. We interleaved fully ambiguous probes (to read out current state of perceptual memory) with biased primes (size/distance cues), randomly disambiguated during the first 300 ms with 10 different bias levels, each lasting 30 ms. We collected 10,000+ trials for three participants. First, we validated the method by computing an average sequence that produced an opposite perceptual dominance in primes: A moderate (50%) bias in favor of the suppressed percept that is gradually reduced to full ambiguity. Next, we repeated the analysis but computed average bias sequences that preceded the dominance change in the following probe. I.e., a prime biasing sequence that established a new perceptual memory. We found the same pattern but with a weaker initial bias. We also computed a bias sequence that reversed the probe (formed perceptual memory) but not the prime itself. Here, an even gentler bias was required. Additional data is necessary to confirm its consistency as such events were rare. In short, to form perceptual memory: gently bias onset perception itself. Open data and methods: https://osf.io/gw7kc/

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Task-relevance of a featural dimension strengthens interocular grouping along this dimension in binocular rivalry

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Providing different stimuli as inputs to each eye typically elicits binocular rivalry: alternations between percepts corresponding to each of the two monocular inputs. However, when the stimuli are presented as a patchwork such that

each eye receives half of one stimulus and half of the other, and the other eye views the respective other halves, then the corresponding halves are perceptually grouped across the eyes. Consequently, percepts of complete, undivided stimuli emerge. This phenomenon is called interocular grouping. Here, in contrast to previous studies that investigated how bottom-up, stimulus-related factors influence interocular grouping, we focused on the influence of top-down, observer-related factors. Specifically, we tested whether designating a stimulus dimension as task-relevant increases the strength of the grouping along this dimension. We used a dynamic image-transformation eliciting a 'motion without movement' to develop stimuli that could evoke interocular grouping along two independent featural dimensions: form (object identity) and motion (motion direction). In separate conditions, observers experiencing rivalry between these stimuli were instructed to report percepts resulting from interocular grouping either along the form or the motion dimension. We operationalized grouping strength as the average proportion of such percepts per trial. After accounting for potential confounders, we found that the task-relevance of a featural dimension strengthens interocular grouping along this dimension. This effect was more pronounced for motion than for form, suggesting that top-down factors have less influence on form than on motion. Taken together, we demonstrate that interocular grouping is influenced by a top-down factors, such as the observer's task.

Acknowledgement: this study was funded by the Preludium grant (2018/31/N/HS6/01032) awarded to M. P. by the National Science Centre, Poland.

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Talk session 3. Multisensory Perception

Structural and functional network-level reorganization in the coding of auditory motion directions and sound source locations in the absence of vision

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hMT+/V5 is a region in the middle occipito-temporal cortex that responds preferentially to visual motion in sighted people. In case of early visual deprivation, hMT+/V5 enhances its response to moving sounds. Whether hMT+/V5 contains information about motion directions and whether the functional enhancement observed in the blind is motion specific, or also involves sound source location, remains unsolved. Moreover, the impact of this cross-modal reorganization of hMT+/V5 on the regions typically supporting auditory motion processing, like the human Planum Temporale (hPT), remains equivocal. We used a combined functional and diffusion MRI approach and individual in-ear recordings to study the impact of early blindness on the brain networks supporting spatial hearing, in male and female humans. Whole-brain univariate analysis revealed that the anterior portion of hMT+/V5 responded to moving sounds in sighted and blind people, while the posterior portion was selective to moving sounds only in blind participants. Multivariate decoding analysis revealed that the presence of motion directions and sound positions information was higher in hMT+/V5 and lower in hPT in the blind group. While both groups showed axis-of-motion organization in hMT+/V5 and hPT, this organization was reduced in the hPT of blind people. Diffusion MRI revealed that the strength of hMT+/V5 – hPT connectivity did not differ between groups, whereas the microstructure of the connections was altered by blindness. Our results suggest that the axis-of-motion organization of hMT+/V5 does not depend on visual experience, but that blindness alters the response properties of occipito-temporal networks supporting spatial hearing in the sighted.

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Touching black and white

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The main purpose of the research was to experimentally investigate whether it is possible to identify haptic variables that can be uniquely associated with specific visual attributes. In two experiments, two basic visual characteristics have been taken into consideration: achromatic color and shape. Color was represented by different density levels of raised dots placed on a smooth surface (the subjective discrimination threshold between the different levels of tactilely perceived density was tested). Regarding shape, a number of 2D (e.g., circle, square, etc.) and 3D (e.g., cube, cone, etc.) figures were tactilely represented by using raised segments on a flat surface.

Both normally-sighted people (blindfolded), and blind people took part to the first experiment. Participants were asked to tactilely explore and to order the different densities in order to create a sequential color scale ranging

from white to black, passing through different shades of gray (and vice versa). Both blind and blindfolded normally-sighted participants spontaneously identified the lower-density stimulus as white and the higher-density one as black, and ordered the intermediate densities as if they were shades of gray as a function of the raised dots density degree. In the second experiment, participants (only blind) were asked to tactilely explore the different surfaces and to recognize them: They easily performed the task. These results pave the way for a systematic study of visual-haptic variables that can be combined with the aim to create an ergonomic conversion code.

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Not all torques are created equal: how vision and intuitive physics guide our grasping behaviour

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A simple heuristic for visually selecting low-torque grasps consists in minimizing the distance to an object's centre of mass. However, grasps that produce similar torques may still require different grip forces. Take for example two orthogonal precisions grips—equidistant from an object's centre of mass—one aligned towards the object's centre of mass and one perpendicular. The aligned torque can be almost effortlessly countered by vertically offsetting thumb and index finger to produce a force couple, with greater offsets requiring smaller forces. Counteracting the orthogonal torque instead requires rotational friction and thus large grip forces. Can humans visually intuit the physical differences between such deceptively similar torques? To test this, we asked human participants (N=7) to grasp L-shaped objects presented at distinct orientations while we tracked their fingertip movements. Stimuli were light-weight (wood, 70g) or heavy (wood/brass composite, 550g), constructed such that their weight distribution yielded aligned and perpendicular high-torque grips. Participants often selected aligned-torque grasps, and when they selected such grasps they consistently offset their fingertips to produce appropriate force couples (p=.0078). This behaviour was further modulated by object mass, with heavier objects eliciting larger offsets (p=.016). Interestingly, participants more strongly biased toward aligned-torque grasps on heavy objects also produced the largest and most effective force couples (r=0.84, p=.018). These patterns were observable before the hand reached the object, demonstrating that these behaviours were visually-driven and predictive. Our findings thus suggest that humans can leverage complex visually-based predictions of physical behaviours when selecting how to grasp and manipulate objects.

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Vestibular contribution to visual target localisation

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Estimating the spatial relationships among objects and our own position in the environment is crucial for survival. Vision is the primary sensory system used to represent spatial information. However, other non-visual signals also play an important role. The vestibular system in the inner ear constantly detects the movement of the head in the 3D space, signalling to the brain our body position and orientation. Previous studies described a vestibular involvement in self-motion, spatial navigation and visuo-spatial memory. However, its contribution to target localisation in space remains unclear. To address this question, we investigated the effects of stochastic Galvanic Vestibular Stimulation (sGVS) on the encoding of the distance of visual targets. A sham stimulation condition was used to control for non-specific effects. Healthy participants were administered with sGVS or sham stimulation while encoding the position of LED lights placed on the floor. The room was darkened and, in addition, participants wore sunglasses to reduce the availability of environmental visual cues. Participants were instructed to focus on the location of the lights, and then localise them by walking towards them. Both accuracy and precision in localisation were measured and compared between sGVS and sham conditions. We observed a decrease in accuracy in the sGVS condition, while precision remained unaffected. Our results demonstrate a clear contribution of the vestibular system in localising visual targets in the environment, suggesting a functional interaction between vestibular and visual inputs during the encoding of spatial cues that influences the ability to reach objects in space.

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The instantaneous impact of a visuo-proprioceptive conflict on the localization of tactile sensations

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If we hold our index fingers horizontally in front of our eyes and point them against each other while gazing into the distance, we have a clear visual impression of a disembodied finger being held between two fingertips. If we instead orient our index fingers vertically, we visually perceive two pairs of fingertips touching each other. In both cases, double vision induces the false impression of seeing more fingertips than we normally do and, thus, a conflict between vision and proprioception about the fingertips positions and their number. Here, we investigated the impact of this visuo-proprioceptive conflict on the localization of the tactile sensations felt by the index fingertips. In two experiments, participants reported their agreement with different tactile interpretations, ranging from the proprioception-only based case with no visual interference, to cases involving different patterns of tactile mislocalizations, or even supernumerary tactile sensations (feeling more touches than actual). Participants agreed most strongly with the interpretation in which the tactile localizations were constrained by their compatibility with visual inputs, demonstrating clear effects of visual capture, but also by their compatibility with the proprioceptively sensed positions of the hands. Notably, participants strongly agreed also with the interpretation in which the tactile sensations were localized on all four fingertips. Our results show that a brief self-induced conflict between proprioception and vision instantly modifies the localization of tactile sensations, leads to multistable percepts, and produces the illusion of supernumerary tactile sensations, advancing our knowledge about multisensory integration of body-related signals.

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Common neuronal assemblies integrate emotion expressions from the face and the voice

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Effective social communication depends on the integration of emotion expressions coming from the face and the voice. Although there are brain regions that respond more to multimodal than unimodal emotion expressions, these activations could either reflect the activity of multimodal neurons or the summed responses of visual and auditory neurons that coexist in the same region. Multi-input frequency tagging of electrophysiological brain responses might reveal a unique non-invasive technique to investigate whether there are neuronal populations that simultaneously process and integrate facial and vocal emotion expressions. We acquired electroencephalographic recordings while participants attended to dynamic fearful facial and vocal expressions tagged at different frequencies (fV, fA). We were not only able to observe responses at the facial and vocal emotion presentation frequencies, but also at intermodulation frequencies arising at the sums and differences of the harmonics of the stimulation frequencies (mfV±nfA) indicating integration of the visual and auditory emotion information into a unified representation. These intermodulation frequency responses were not present in the signal and therefore arise only if neuronal populations integrate signal from the two sensory streams. Interestingly, intermodulation frequency responses were absent in a control condition with mismatched facial and vocal emotion expressions. Our results provide for the first time a direct and non-invasive evidence in support for the existence of neuronal populations that simultaneously process and integrate emotion information from the face and the voice.

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Talk session 4. Face Perception

Mooney Face Image Processing in Deep Convolutional Neural Networks Compared to Humans

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Deep Convolutional Neural Networks (CNNs) are criticised for their reliance on local shape features and texture rather than global shape. We test whether CNNs are able to process global shape information in the absence of local shape cues and texture by testing their performance on Mooney stimuli, which are face images thresholded to binary values. More specifically, we assess whether CNNs classify these abstract stimuli as face-like, and whether they exhibit the face inversion effect (FIE), where upright stimuli are classified positively at a higher rate compared to inverted. We tested two standard networks, one

(CaffeNet) trained for general object recognition and another trained specifically for facial recognition (DeepFace). We found that both networks perform perceptual completion and exhibit the FIE, which is present over all levels of specificity. By matching the false positive rate of CNNs to humans, we found that both networks performed closer to the human average (85.73% for upright, 57.25% for inverted) for both conditions (61.31% and 62.70% for upright, 48.61% and 42.26% for inverted, for CaffeNet and DeepFace respectively). Rank order correlation between CNNs and humans across individual stimuli shows a significant correlation in upright and inverted conditions, indicating a relationship in image difficulty between observers and the model. We conclude that in spite of the texture and local shape bias of CNNs, which makes their performance distinct from humans, they are still able to process object images holistically.

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7T fMRI mapping of the visual-word form area relative to other category-selective areas on the surface and in representational space

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The occipito-temporal cortex (OTC) allows us to determine the category of the shapes and objects that we see. This visual categorization is enabled by category-selective areas and patterns of neural activity across whole OTC. OTC organizes categories according to various abstract dimensions such as animacy. For one area in particular several important questions remain unanswered: the visual word-form area (VWFA). Its location and its function relative to several other category-selective areas and to category dimensions has not been investigated at a high spatial resolution. Other questions also remain unanswered: is its relative organization different between hemispheres, how many subregions are there, …?

To understand how OTC allows categorization of words, relative to other categories and to the several dimensions these categories vary on, we investigate both the activation space (high-resolution surface-maps of category-selective activation) and the representational space (using multi-voxel pattern analysis (MVPA)). To this end, we presented 19 subjects with images of 20 different categories using 7T fMRI.

The activation space reveals that words-selective activation always clusters together with activation specific to human-related categories like faces, bodies and hands, and these activations partially overlap. On the ventral surface, words-selectivity is located on the more lateral and animate side of OTC, even though they are not animate shapes. This is unlike the organization of the representational space of the included categories, that reveals that words do not organize according to animacy or any other category dimension, but rather hold a special place within this space.

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Optimizing face identification performance: The influence of base rates and payoffs

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Matching identity of unfamiliar faces is challenging. Images of the same person can look very different and images of different people can look similar. Distinguishing match vs. mismatch pairs has been conceptualized as a perceptual problem, with robust individual differences in sensitivity (d′) and response bias (criterion, c) and limited efficacy of training protocols. This ignores effects of base rates (proportion match trials) and payoffs (cost of misses vs. false alarms). Inspired by economic models, we investigated the influence of base rates and payoffs on d′, c, and utility (maximizing points earned). Participants (n=252) completed two rounds of an identity-matching task in which points determined the number of tickets for a cash draw. Round 1 was neutral, with equal match vs. mismatch trials and identical costs (-5 points) for misses (responding different on match trials) and false alarms (FAs, responding same on mismatch trials). In Round 2, participants were assigned to one of three conditions: high base rate (80% match trials), costly FAs (-30 points for FAs, -2 points for misses), and high base rate + costly FAs. As predicted by the expected value function, c shifted in Round 2 (most conservative in the costly false alarm condition, most liberal in the high base rate condition), with no shift in d′. Participants in the high base rate condition adopted a more optimal criterion than participants in the other two groups. Our findings highlight the importance of integrating decision making into models of face identification and have implications for applied settings.

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Individuals with ASD show an increased influence of body posture on facial expression perception

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Facial expression perception is influenced by context. For instance, affective body postures bias facial expression perception toward the emotion conveyed by the body. Amongst typical adults, the magnitude of this context effect is determined by the precision with which observers represent facial expressions, with lower precision leading to a greater influence of body posture. Individuals with Autism Spectrum Disorder (ASD) show reduced facial expression discrimination abilities, which should lead to larger influences of body posture on facial expression perception. However, individuals with ASD also exhibit a local processing bias, which should limit their ability to incorporate contextual cues into global percepts, and would thus lead to an opposite effect, i.e., a smaller influence of body posture. Here, we address these competing hypotheses. We used online psychophysical methods to characterise the precision of isolated facial expressions and the influence of body posture in autistic and neurotypical individuals. In line with previous research, we found that autistic individuals had poorer facial expression discrimination ability than neurotypical individuals. Both groups showed the expected influence of body context on facial expression perception, but this effect was larger in the ASD group. Crucially, we found that, in both groups, the magnitude of the context effect was related to the observers' facial expression discrimination ability. These results suggest that, in autistic individuals, similar principles may govern the integration of facial expression and body posture information as in neurotypicals.

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Neural representations for dynamic and subtle facial expressions

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Faces contain many nuanced visual differences that change over time. It's not yet understood how these dynamic visual features are transformed into behaviorally useful representations of emotional expressions. A large body of literature have studied the spatial and temporal processing of expressions, but only a few have used stimuli containing subtle perceptual changes. In the present study, we used 48 short videos where faces varied in intensity and category (happy, angry, surprise) of expression. The duration of the whole clip was 720 ms and expression changed in the middle of the clip (duration of change 240 ms). The magnitude of change was always 25% in a morph continuum from neutral to full expression or between two different expressions. We measured both fMRI and EEG responses to these video clips and compared the neural response patterns to the predictions of several models based on image features and behavioral ratings of the stimuli. In fMRI, the inferior frontal gyrus face area (IFG-FA) carried information related only to the intensity of the expression, independent of image-based models. Superior temporal sulcus (STS), inferior temporal (IT) and lateral occipital (LO) areas contained information of both expression category and intensity. In EEG, coding of expression category and low-level image features were most pronounced at around 400 ms. Expression intensity model did not, however, correlate significantly with EEG. Our results show a specific role for IFG-FA in coding of expressions and suggests that it contains abstract representations of expression intensity, invariant to image properties and emotion categories.

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Electrophysiological markers of face processing and predictive coding and the uncanny valley

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The uncanny valley predicts negative evaluation of near humanlike entities. Although the cognitive and neural mechanisms of the effect are not yet understood, sensitivity to deviations detected by configural face processing and expectation violation in predictive coding have been proposed. A direct link between electrophysiological markers of face processing or prediction errors and uncanniness have however not yet been investigated. This study investigates the effect of inversion of normal, virtual, mismatched (mismatching realism of face and eyes), and 'Thatcher' faces on uncanniness ratings and event-related potentials (ERPs) of face processing (P100, N170) and predictive coding (N400) in n = 80 participants. It was predicted that a disruption of configural processing reduced uncanniness of uncanny faces, that uncanny faces elicited higher ERPs than non-uncanny faces when upright, and that increased ERP amplitudes can predict uncannines ratings. First, mismatch and Thatcher faces were rated as more uncanny

than normal and virtual faces, but only when faces were presented upright. P100 amplitudes at TP8 and PO7 were higher for upright Thatcher (but not mismatch) compared to normal faces. N170 amplitudes at TP8, TP10, and PO7 were significantly higher for mismatch and Thatcher faces compared to normal faces when presented upright. N400 amplitudes were only increased for Thatcher (and not mismatch) faces at TP8, TP9, and PO7. Finally, N170 and N400 amplitudes at PO8 significantly predicted uncanniness ratings across faces. In total, the results depict neurophysiological correlates of face uncanniness as an increased face processing need and expectation violation.

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Talk session 5. Perception & Action I

Object-based active inference

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The world consists of objects: distinct entities possessing independent dynamics and other intrinsic properties that are theirs alone. For organisms to interact with the world intelligently, this important fact must be reflected in the neural computations underlying perception and action. Perceptual inference must translate sensory inputs into the bound-together features that describe each separate object. The resulting object-based neural representations then form a natural basis for planning behavior, to manipulate the inferred objects to the organism's advantage. But how can the necessary computations for object-based perception and action be realized in neural circuitry? To address this important question, we introduce "object-based active inference" (OBAIF), a new framework that marries the principles of active inference with deep, self-learning, object-based neural networks. Our proposed neural architecture functions like a Bayesian filter that iteratively refines perceptual representations. Through selective attention, sensory inputs are routed to high-level object modules that encode each object as a separate probability distribution, whose evolution over time is constrained by an internal model of action-dependent object dynamics. These object representations are highly compact and abstract, enabling efficient unrolling of possible futures, and (quasi-)symbolic reasoning, in order to select appropriate actions. Our results show that OBAIF networks successfully learn (without supervision) to parse synthetic videos into their constituent (moving) objects, and to manipulate these objects to achieve arbitrary objectives. Finally, as a first foray into more complex cognitive tasks, we show that our OBAIF approach can be applied to solve an active version of the classic visual search paradigm.

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Can you follow your friends? Ensemble perception vs. selective attention in human crowds

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All models of collective motion in human and animal groups assume ensemble averaging of one's neighbors. Yet when walking in a crowd, it seems we can follow our friends and ignore everyone else. We adapted the Multiple Object Tracking paradigm to study attention in crowds while walking in VR. Experiment 1 tested whether attention to a subset of neighbors in a virtual crowd spontaneously influences following behavior. On each trial, a target set flashed and participants were instructed to track them while walking with the crowd. The travel direction of Targets or Distractors was perturbed ($\pm 20^{\circ}$) during the trial. We found no effect of attention: participants' final heading was equivalent to a Control (track-all) condition (BF01 = 11.90), consistent with ensemble perception. Experiment 2 explicitly instructed participants to follow the targets. There was a small effect of task-relevant attention: final heading was between the Control ($p<.001$) and Targets-Alone (maximal response) conditions ($p<.001$). Experiment 3 tested spontaneous grouping by familiarity. Participants were trained to recognize avatar "friends" (which replaced targets) and instructed to walk with the crowd. There was a small effect of familiarity: final heading was between Control ($p<.001$) and Friends-Alone ($p<.001$) conditions. Experiment 4 explicitly instructed participants to follow their friends. This time they exclusively followed the friends: final heading was equivalent to Friends-Alone (BF01= 9.75). The results were simulated by suppressing distractors during ensemble averaging. We conclude that crowd behavior is normally characterized by ensemble perception, but it can be broken by the intention to follow your friends.

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Eye-hand interaction in anisotropic depth perception

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Upward distances are perceived as larger than physically equal downward or distances in front of us. This anisotropy of perceived distance is related to perception-action interactions since distances are perceived as larger in direction requiring more effort for action performance. According to that, the aim of the present research was to directly compare visually and haptically estimated distances. An experiment was performed in a dark room (reduced cue situation) on 19 participants whose task was to match distances of dim light stimuli in two directions, vertical above them and horizontal in front of them. We used three standard stimuli distances, 60, 50, and 40cm. Participants would visually perceive standard distance in one direction, and then match the distance in the other direction by moving the other stimuli by hand, without looking at it. Also, they would perceive standard distance in one direction reaching it by hand, while looking at the other stimuli and guiding the experimenter to move it until they perceive distances of two stimuli as equal. Results show significant differences in the estimated distance in two directions for both, haptically and visually guided estimates. Anisotropy does appear in both conditions in the expected direction, vertical distances are perceived as larger. Anisotropy intensity calculated as a ratio between vertical and horizontal distance estimates does not vary depending on haptic or visual conditions. These results are in line with taking effort into account for explaining perceived depth anisotropy.

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Phasic alerting effects on the Trail-Making-Test

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Quickly adapting to new information plays an essential part in interactions with the environment. To quickly react to changes in the environment, the brain has to be in a state of response readiness. Warning stimuli support response readiness. Responding is facilitated when warning stimuli appear shortly before visual targets (the phasic alerting effect). This effect is typically studied using simple visual detection and discrimination tasks, but it is unknown if it exists also for more complex sensorimotor tasks. Therefore, we investigated how phasic alerting affected performance in a variant of the Trail-Making-Test (TMT), a neuropsychological test assessing cognitive processing for visually-guided sensorimotor actions. Besides the TMT, participants performed a classic alerting paradigm using a choice reaction task. Results showed that alerting sped up responding in both the classic choice reaction task and the TMT. In the TMT, however, alerting effects were confined to the first action of an action sequence but left later actions unaffected. These findings indicate that phasic alerting has only short-lived effects on readiness for action and perception that do not persist while performing more complex tasks.

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Virtual occlusion effects on the perception of self-initiated visual stimuli

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Sensory attenuation (SA) refers to the observation that self-generated sensory input is typically perceived as less intense than externally generated sensory input. Recent empirical work suggests that SA provides a window into predictive processing of the sensory and cognitive apparatus, and thus may allow to study the core mechanisms underlying human perception and behavior. Using a virtual reality (VR) environment, we aimed to test the ability of motor-based forward models and the predictive processing account in explaining sensory attenuation of visual contrast associated with self-initiated actions. Specifically, we asked participants (N=30) to decide which of two Gabor patches was of higher contrast in a VR situation where one of the stimuli could appear behind the participants' invisible moving hand ("virtual occlusion"). In a repeated measures design, we examined the influence of the initiation of motor behaviour and temporal predictability. Stimuli either appeared immediately after motor behavior, with a varying delay or independent of the participants' actions. Our results suggest that the perceived intensity of self-initiated sensory input is not only modified by efference copies, but also by temporal predictability as well as proprioceptive cues about the location of one's own hands. Taken together, our findings are more compatible with the predictive processing account than with motor-based forward models.

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Are interaction movements smoother in Mixed Reality than in Virtual Reality?

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Mixed Reality (MR) is promising to fuse the visualization potentialities of Virtual Reality (VR) with the physical properties of the real world, thus allowing a more natural interaction in virtual environments, and preserving visuomotor coordination. Recent works show that the lack of haptic and tactile feedback produces significant differences in grasping actions performed in immersive VR, with respect to the same actions performed in the real world. In this

work, we perform interaction tasks in three scenarios: an MR environment implementing an ecological object substitution technique, in which the user touches real objects tracked in real-time and sees a virtual counterpart; a classical VR environment, in which virtual objects do not have any real counterpart; and a real scenario. We detect hands and finger positions during the experimental sessions. We compute the Minimum Jerk Cost function as a metric to compare movements in the three different modalities, assuming that a major goal of motor coordination is producing the smoothest possible movement of the hand. From preliminary results, movements costs in VR are 120% higher than the costs of the movements in MR. This could be due to the lack of physicality when grabbing virtual objects without a real counterpart. Furthermore, the costs of movements obtained in MR are 40% higher than those obtained in the real scenario, indicating that such a system could lead to more realistic and efficient human movements with respect to a VR system.

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Poster session 1. Face Perception - 1

The effect of face outline size, face components sizes, and spacing between face components on Flashed Face Distortion Effect

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The Flashed Face Distortion Effect (FFDE) refers to the phenomenon in which face is perceived distortedly when a series of eye-aligned faces are presented at a rapid pace in the periphery of visual field. The purpose of this study is to examine whether the FFDE is related to the crowding effect in which the face shape is perceived distortedly via interference between face components in the peripheral vision. In Experiment 1, the effect of face outline size and spacing between face components on the FFDE was studied. In Experiment 2, whether effect of the spacing between face components varies depending on the size of the components was examined. In Experiment 3, effect of face outline size and face components size on FFDE was investigated. The results of Experiment 1 and 2 showed that the smaller the face outline, the stronger the distortion was perceived. The reverse pattern was found in the size of face components. Face distortion was also observed when face outline and size of faces components were mixed. However face distortion was not affected by spacing between face components. In experiment 3, the larger the size of the face components, the stronger the distortion was perceived. The similar pattern was found when size of face components were mixed. These results showed that FFDE is related to the crowding effect and the shape-contrast effect.

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Excluded developmental prosopagnosia cases exhibit impairments in face processing

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Developmental prosopagnosia is a disorder characterised by difficulties when recognising faces. Roughly half of all people who believe they have this condition do not meet the commonly used single case analysis criteria for a diagnosis, resulting in their almost complete absence from the scientific literature. Here we assessed whether these excluded prosopagnosia cases could exhibit impairments in a variety of face processing tasks at the group level. As expected, they were impaired on an unfamiliar face recognition task (Cambridge Face Memory Test), a famous faces test and a face perception task. Strikingly, these cases had holistic perception impairments that were comparable to the cases who did meet criteria, indicative of problems in extracting key information that is thought to aid the recognition of facial identity. Owing to their objective deficits on all tasks, we argue excluded cases should be included in our future work. Moreover, as the prosopagnosia index questionnaire more accurately categorised all cases than other measures, this should be the primary tool for a diagnosis. Doing so will advance scientific knowledge, allow us to more accurately estimate effect sizes of impairment and treatment efficacy, and identify potential commonalities and differences from those cases who do meet single case criteria.

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The Effects of Negative Emotions on Mental Representation of Faces

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Face detection is an initial step of many social interactions involving a comparison between a visual input and a mental

representation of faces, built from previous experience. Furthermore, whilst emotional state was found to affect the way humans attend to faces, little research has explored the effects of emotions on the mental representation of faces. Here, we studied how naturally occurring anxiety and depression affect mental representations of faces. To this end, we used a novel reverse correlation technique inspired by Gosselin and Schyns', (2003) 'Superstitious Approach'. In two sessions, on separate days, participants were presented with 'colourful' noise stimuli and asked to detect faces, which they were told were present. Based on the noise fragments that were identified by the participants as a face, we reconstructed the pictorial mental representation utilised by each participant in each session. Across participants, we found significant correlations between the size of the mental representation of faces and their level of depression, and between the variations in size of the mental representations and level of depression within participants. Our findings provide a preliminary insight about the way emotions affect appearance expectation of faces. To further understand whether the facial expressions of participants' mental representations reflect their emotional state, we are conducting a validation study with a group of naïve observers who are asked to classify the reconstructed face images by emotion. Thus, we assess whether the faces communicate participants' emotional states to others.

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Let's face reality—test-based face recognition and real-life eyewitness identification in children and adults

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Faces offer a plethora of social information and their perception guides and shapes our everyday interactions. Furthermore, tasks in applied settings such as eyewitness testimonies rely on accurate face recognition. Research on face processing typically uses standardized pictures of faces as stimuli, leading to the open question how test-based face recognition transfers to recognition in real life and how that transfer might differ across the lifespan. Here, we investigated face recognition in a lineup setting including exposure to a staged crime and a real-person lineup and related this performance to test-based face recognition (Cambridge Face Memory Test, CFMT) in 27 children (17 female, M= 6.90, SD = .84) and 21 adults (13 female, M = 24.0, SD = 3.91). In the lineup, adults correctly identified the culprit more often than children ($\chi2(1) = 5.259$, $p = 0.022$, Cramer's $V = 0.331$) and their confidence ratings increased diagnosticity of identification (Area under the Receiver Operating Characteristics curve (AUC) = .913, $p < .001$) while this relationship was not shown in children (AUC = .528, p = .809). Performance in the CFMT and lineup correlated rather moderately and significantly only in children (children: $\tau b = .333$, $p = .023$; adults $\tau b = .256$, $p = .093$). Test-based face recognition performance thus cannot be used to predict or validate lineup performance. The perceptual aspects of seeing a person in real life versus on a photograph should be considered when evaluating face recognition performance both in the lab and in applied settings.

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Recognising Older and Younger Faces: Mixed Evidence for an Ageing Asymmetry Effect

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Human faces change considerably in appearance over time. Previous research examining the ability to recognise identity across changes in age suggests an ageing asymmetry effect, with younger instances of an identity (childhood photographs) being more difficult to recognise than older instances (adult photographs). To explore this effect, we used statistical models of face recognition (PCA + LDA) and behavioural studies to examine whether an ageing asymmetry effect is present for images taken across the adult lifespan. Participants/models were trained on a set of young adult faces (e.g., 20-30-years-old), with each facial identity depicted in multiple images. The ability to recognise instances of the trained identities at an older age (e.g., 60-70-years-old) was then tested (young-to-old). We also ran a condition in which the age of the training/test faces was reversed (i.e., training with older instances and testing with younger instances of the same identities; old-to-young). An ageing asymmetry effect was present in the modelling data, with greater accuracy for the young-to-old condition than for the old-to-young condition. However, across three behavioural experiments, no evidence was found for an ageing asymmetry effect; participants were equally accurate at recognising faces from older and younger images, regardless of the age of the training set. Our findings suggest that the ageing asymmetry effect found in previous research is likely specific to child faces, which are particularly difficult to recognise. We also highlight a need to understand differences between human

and computational models of face recognition, in addition to similarities.

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Effects of fusion and unreliable AI on face matching

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Psychological studies have established that unfamiliar face-matching is error-prone. Research has explored the use of AI-based facial recognition systems to support decision-making in face matching tasks. The current study explored the effects of reliable AI, unreliable AI, and no AI support on human face-matching performance. Stimuli consisted of 40 pairs of faces taken from the Kent Face Matching Test (KFMT). In the reliable AI group, 33 participants were presented with face pairs and given identity information that was consistent with the stimuli, using labels in the form of 'same' on a match trial or 'different' on a mismatch trial. In the unreliable AI group, 35 participants matched the same faces, where some of the image pairs were inconsistently labeled. There were 32 participants in the no AI-support group where no advice was provided. The AI scores and human ratings from the no AI-support group were combined to create a fused human-AI group. Confidence in a decision and trust ratings on the advice given was obtained in each trial. Results indicate an effect of using unreliable AI on bias and no significant difference in percentage accuracy, sensitivity, and trust ratings between the groups. Further exploratory analyses showed an effect on trust between consistently and inconsistently labeled trials. The study provides confirmation for the improved accuracy of fused human ratings and AI scores and initial support for the role of trust in the interaction between human face-matching decision-makers and facial recognition algorithms. Directions for future studies on trust calibration are discussed.

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Think of concealing your identity? Wearing face masks has a different effect from wearing sunglasses

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Wearing face masks has become the face of the COVID-19 pandemic. Yet, the effect of occluding the lower part of the face on face identification is still being understood (Carragher & Hancock, 2020; Freud et al., 2020; 2021; etc.). In contrast, masking the upper part (e.g., covering the eye region with sunglasses) impaired face identification (Graham & Ritchie, 2019; Mansour et al., 2020; etc.). Here, we investigated how wearing sunglasses and face masks could have different effects on face identification during face memory tests. Observers (N = 24) viewed faces under three conditions: (1) in full, unoccluded, (2) wearing sunglasses, or (3) wearing surgical masks. In each condition, observers studied 21 faces in a randomized sequence (each face presented twice; stimulus duration: 2000 ms/presentation), followed by a memory test with 42 faces (21 studied and 21 unseen; stimulus duration: 350 ms) under the same condition. Observers judged whether each test face was studied before or novel. Results showed that sensitivity (d' = 1.47 for full faces) dropped only with sunglasses (d' = 0.71), but did not change significantly with surgical masks (d' = 1.32). However, observers were significantly biased (c = –0.22) towards incorrectly identifying unseen faces as seen for faces with surgical masks, but not for faces with sunglasses or for full faces. Thus, the upper and lower parts of the face are both crucial to face identification, but performance from partial occlusions here suggests their divergent roles in face identity processing.

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Face masks undermine first-glance affective responses to emotional facial displays

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Presenting pictures of people with and without facial masks, we employed a 6-AFC paradigm (emotional states happy, angry, fearful, sad, disgusted, and neutral), accompanied by a confidence rating of the own recognition performance. Simultaneously, we recorded participants' gaze via an eye tracker and their facial expression via a HD video camera to test facial expression mimicry effects (using the Fraunhofer SHORE library). We replicated the general findings of previous studies, including dramatically impaired recognition of disgust (mostly confused with angry, sad or happy) and moderately impaired recognition of happy, angry, and sad expressions when facemasks were present. Across all emotional states, participants' confidence about their decision for all emotions was clearly reduced, even for the non-impaired recognition of the emotional states fearful and neutral. Participants efficiently adapted their gaze behavior as soon as masks were displayed by reprogramming their fixation pattern on indicative facial areas only (eyes area when masks

were visible compared to a much more widespread fixation pattern across eyes and upper mouth area without mask. For facial mimicry, we observed specific behavior only for happy faces which were mimicked by increased own smiling, but only when the mouth was not covered. The overall pattern of results supports the view that we do not only lose the effective way to read emotional states of faces with mouth-nose masks. Actually, we also lose the immediate affective response to such facial displays, and probably this will lead to a reduction of first-glance empathy with the respective persons.

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What makes humans detect a face?

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Humans are fast and accurate in detecting faces across different contexts. However, it is largely unclear what factors affect human face detection performance. Here, we take a first step to address this question by measuring face detection behavior and comparing it to various stimulus attributes in an online study. We used images belonging to 13 different indoor scenes (e.g., bookstore, bedroom) as stimuli. For each scene type, we selected 20 images with a single face present in the scene, and created 20 corresponding images without face by manually removing the face from each image. For each of the 520 images, subjects (n=120) performed a speeded judgment regarding the presence (or absence) of a face. We found that, while face detection accuracy was at ceiling (~99% correct), response times varied reliably (split-half reliability: .84) across scenes and images (RT mean $\pm$ STD: 440 $\pm$ 80 ms). These variations in response times could not be simply explained by the size or location of the face (Spearman's $|r| < 0.08$), nor by features extracted from convolutional neural networks (CNNs) trained on scenes, faces or objects (all $|r| < .05$). Interestingly, however, we found that the magnitude response of a mid-level layer in the face-trained CNN was significantly correlated with human response times for images containing a face ($r = -.15$). These initial results reveal the complex interplay of features and factors shaping human face detection and may open the door to a deeper understanding of how humans detect faces in natural scenes.

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The Episodic Prototypes Model (EPM): On the nature and genesis of facial representations based on a face-verification-task

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Faces undergo massive changes over time and life events. In order to still be able to recognize a familiar face, we need a mental representation which is flexible enough to cope with existing visual varieties, but which is also stable enough to rely on the characteristic outward appearance of underlying prototypes. Neither the classical prototype face-space model relying only on one exhaustive mental representation per face, nor the exemplar-based face space referring to a vast number of single representations per face, can cope with these requirements. We created a new, ecologically valid Episodic Prototypes Model which is based on a low number of needed episodic prototypes which refer to idiosyncratic Episodes of Life (e.g., early adulthood, mature age). Such an episodic view of mental representation allows for efficient storage, as the number of needed prototypes is relatively low, and it allows for the needed variation within a prototype that keeps the everyday and steadily ongoing changes across a certain period. We could successfully show that facial representations are highly dependent on temporal aspects being in accord with such prototypes. The present study focused on providing evidence for the superiority of the EPM over rather exhaustive prototypes models by using implicit measures (RT) in a face-verification-task. We could reveal that episodic prototypes clearly outperform visual depictions of exhaustive prototypes, supporting the general idea of our approach.

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Edges and Shading: Critical cues accounting for the horizontal tuning of face identification

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Face identity recognition is core to human social life. It relies on edge-based as well as on shading information. Recent evidence showed that human face recognition depends on stimulus orientation content, with peak performance obtained in the horizontal range, and depicting a bell-shaped decrease in sensitivity as stimulus orientation content shifts towards vertical. This horizontal tuning of face recognition is found early in human life and continues to develop until adulthood, along with the progressive specialization of the face processing

system. The present study aims at characterizing the nature of the visual information delivered by the horizontal range of face identity information. To do so, we measured the effect of face inversion and contrast negation to disrupt the access to edge-based and shading information, respectively, and investigated how they influence the horizontal tuning of face recognition. Participants viewed pictures of familiar celebrities, filtered to preserve information in a selective orientation range (0° to 150° in steps of 30°). Filtered faces were presented either upright, inverted, or contrast-negated. Both inversion and contrast-negation significantly decreased face recognition performance across all orientations, with the strongest decline in the horizontal range. The inversion and negation effects were equivalent and significantly stronger in the horizontal range than in the vertical and close-to-vertical obliques. The importance of facial horizontal cues for face recognition may thus be due to this range conveying both edge-based and shading information, i.e. presumably the two major cues to recover face identity.

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The development of personally familiar face recognition during childhood

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Adults are experts at recognising familiar faces in images that incorporate natural within-person variability in appearance. Relatively little is known about the development of this ability during childhood. We tested children's ability to recognise a highly personally familiar face with which they have had extensive experience — that of their own parent. Fifty-six children (4-7- year-olds) were shown previously unseen images of their parent intermixed with images of other people. Children completed a child-friendly face recognition task in which they were required to identify their parent and put all their photographs inside a pretend house. We manipulated whether the images were similar or dissimilar to the child's prior experience by presenting images of the parent taken both before and after their child was born. Four- and five-year-olds were less sensitive to identity than were six- and seven-year-old children when viewing images taken before they were born, but sensitivity did not differ when viewing images taken after their birth. These findings suggest that even for highly familiar faces with which children have extensive experience, younger children have difficulty tolerating changes to appearance that go beyond their direct experience. We suggest that the development of the ability to form robust representations of identity may be linked to changes in face-specific experience (e.g., learning many faces when children start school).

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An inconvenient association between familiarity and distinctiveness ratings of familiar faces

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New ratings data suggest that the more a famous face is judged familiar, the more it is judged distinctive, that is different from other faces. The same ratings obtained on unfamiliar faces do not show the same positive association. High distinctiveness ratings on celebrities might thus reflect an illusion of distinctiveness—a subjective impression that does not match the objective distinctiveness of a given face's features. Such illusion, making objective distinctiveness ratings difficult to obtain for faces that are widely known, could be problematic for building well-controlled materials to study familiar face recognition, the impact of distinctiveness itself or individual differences in face recognition abilities. To objectify this phenomenon and test if it can be mitigated, we examined the links between familiarity and distinctiveness ratings obtained from full headshots of celebrities and between familiarity and compound distinctiveness ratings calculated from ratings on four different isolated facial parts. Isolating facial parts is known to disrupt facial recognition, and so ratings of isolated parts should be less influenced by familiarity than ratings of headshots. We found that the association between familiarity and distinctiveness was stronger than between familiarity and compound distinctiveness, both at the individual participant level and at the face item level. The eyes and external features were the most distinctive while the mouth and the nose areas were the least. We will discuss the implications of this illusion of distinctiveness for future research on familiar face recognition and how it might further our understanding of information contained in facial representations.

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Facial features stored in visual working memory revealed using classification images

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Although some facial features (e.g., eyes) are known to be especially important for face identity perception, it is still unknown how face information is stored in visual working memory, and how face representations decay over time. Here, we used psychophysical reverse correlation

(classification images) to directly reveal features stored in visual working memory. We also measured internal noise with the double-pass method to study whether increasing internal noise could explain forgetting in visual working memory. The face images were grayscale with 40 unique identities. We created numerous stimuli by morphing individual facial features between two identities using morph values independently drawn from a uniform distribution. In a modified same-different task, observers were first asked to memorize one stimuli. After a retention interval (1 or 4 s), a second stimulus was shown. Observers responded whether this was a "similar" identity, where features were, on average, only slightly randomized towards another random facial identity, or a "different" identity, where features were randomized towards another identity by a large amount on average. Classification images estimated using generalized linear regression, where randomized feature values predicted observers' "different" responses, showed how each feature was weighted in memory-based decisions. We found high weighting for the mouth and especially the eyes. Feature weightings in the longer retention interval were similar but lower than in the shorter retention interval, suggesting forgetting is not feature-specific. We found that internal noise increased in the longer retention time, which potentially explains forgetting in visual working memory.

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Poster session 2. Attention – I

Motion as a game-changer? Attention bias in spider phobics for moving spiders: a visual search task

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The vigilance-avoidance bias for threat plays an important role in the etiology and maintenance of specific phobias. For instance, spider-phobics detect spiders faster and subsequently avoid them. However, previous studies mostly used static images to investigate the attention bias. Since motion is potentially associated with increased threat, motion might influence the early attention bias towards phobic and threat-relevant stimuli. Thus, we aim to investigate the effect of motion on attentional capture in spider-fearfuls by using point-light and naturalistic videos. Point-light stimuli consist of moving dots, each representing a joint. These moving dots simulate biological motion, e.g. a walking human or cat, without the actual body being visible. Spider-fearful and non-spider-fearful subjects completed a visual search task. Stimuli were phobic (spiders), threatening (snakes), and neutral (cats, pigeons) animals. The search displays contained moving targets, or moving distractors (point-light/ naturalistic videos), or static targets and distractors (video images). Participants searched for a specific animal category as quickly as possible. Response times were recorded. We hypothesized that spider-fearfuls respond faster to spider targets than non-spider-fearfuls and that spiders distract them more easily. We also expected faster responses to moving targets and slower responses to moving distractors. The comparison of point-light stimuli and naturalistic videos shows the influence of motion (excluding other features) on the attention bias. The study underlines the importance of ecologically valid experiments in the field of specific phobias. Future studies should additionally measure eye-movements to investigate whether the effects are due to attentional capture of phobic stimuli or prolonged disengagement.

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Is pupil-linked arousal a marker of model violation but not model update?

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Humans build internal models of environmental regularities to make good predictions. When deterministic models are violated, a form of abrupt, unexpected, uncertainty is generated that permits fast reset and change, requiring cognitive effort that induces arousal; by contrast, relatively stochastic models induce a form of continual, expected, uncertainty and so update more sedately. The locus coeruleus and norepinephrine system (LC-NE), whose activity is correlated with pupil dilation responses (PDRs), helps regulate arousal and the changes to models. Following Zhao et al. (Nature Communications, 2019), we investigated whether PDRs respond to uncertainties that result in model violation (unexpected uncertainty) or model update (expected uncertainty). To create uncertainties, we generated auditory patterns consisting of random or repeating sequences of brief tone pips. We used a switch from a regular to a random pattern to examine unexpected uncertainty, from a random to a regular pattern to examine expected uncertainty, and, as a novel contribution, from one regular pattern to another one to examine unexpected uncertainty followed by certainty. We presented those auditory patterns to 8 participants, instructed them to find silent gaps for keeping their attention on the patterns, and measured PDRs. Results replicated Zhao et al. (2019) with PDRs to unexpected uncertainties. In addition, we found a pupil constriction response when certainty followed unexpected uncertainty. Results suggest that pupil dilation might be driven

by model violation, while pupil constriction might arise as regularities are discovered.

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Attentional guidance by spatially global versus spatially specific search templates

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Search templates are working memory representations of target defining features that guide attention to objects of interest in a spatially global fashion (because target locations in visual search are typically unknown). Previous research has suggested that when multiple target colours are task relevant, multiple colour templates are activated in parallel to guide attention in a highly efficient–spatially unspecific–search mode. But is such spatially global guidance (knowing what to look for) as efficient as spatially specific guidance (knowing where to look for)? To test this, we measured the N2pc component of the event-related potential while participants searched for spatially-defined (location task) or colour-defined (colour task) targets in circular search arrays with four differently coloured objects (letters or digits). Search arrays were preceded by cue displays consisting of a circular array of eight grey placeholders. In the location task, one (single template) or two (multiple templates) placeholders changed colours and served as cues indicating the possible target location(s), the cue colour being task irrelevant. In the colour task, the coloured placeholders indicated the upcoming one or two target colour(s) and the cue location was task irrelevant. Mirroring previous findings, N2pc components in multiple compared to single colour search were slightly delayed. These small template load costs are thought to reflect the mutual inhibition caused by multiple co-activated attentional templates. Critically, we also measured comparable N2pc delays in multiple compared to single location search. This suggests that spatial uncertainty does not reduce search efficiency in multiple template search.

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The causal role of parietal alpha activity in coding spatial and feature-selective attention: A concurrent TMS-EEG study

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Selective attention is a fundamental cognitive mechanism that allows our brain to prioritize relevant information and suppress distracting information. These selective mechanisms can operate in different ways based on either spatial location or visual features of an object, such as colour, shape, and orientation. Although many studies have suggested that parietal alpha activity plays an important role in spatial attention, it remains unclear whether and how alpha activity can causally influence the neural coding of both objects and features. In this pre-registration, we aim to combine the transcranial magnetic stimulation (TMS) entrainment protocol with concurrent electroencephalography (EEG) recording to causally manipulate alpha activity around the right intraparietal sulcus (IPS) and to examine the consequence for stimulus coding when participants direct their attention in space (spatial attention) and to particular object features (feature selective attention). Using time-frequency analysis, we will examine the effect of TMS entrainment on power and inter-trail phase coherence in the alpha band around the right IPS. Capitalising on recent advances in multivariate pattern analysis in time series neuroimaging data, we will assess whether the parietal alpha activity is causally associated with the coding of attended/unattended objects and task-relevant/irrelevant features. Our results will not only examine the effect of online TMS entrainment in studying human cognition, but can also provide empirical insights into popular theories on spatial attention, feature-selective attention, and their potential interactions.

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Cognitive load has no influence on Interference during emotion-Induced blindness

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Due to evolutionary reasons, emotions receive preferential processing and are found to impede attention. Emotional interference effects are also evident in emotion-induced blindness (EIB), which is characterized as an inability to recognize a neutral target after being distracted by emotional distractors. According to load theory, the level of cognitive load determines the level of interference. Our research uses a theoretical understanding of cognitive load to explore if including it can help to prevent the emotional disruption shown in EIB. We manipulated load, emotions, and temporal distance in three studies to see how they influenced neutral target orientation detection. At the end of each trial, participants reported the orientation of the target (left or right), which was presented after the emotional distractor, and recalled the load displayed just before rapid stream of images. In all three experiments, EIB was greater

in emotional than neutral distractors, replicating the conventional EIB effect. However, EIB was unaffected by load in both high and low load conditions, implying that emotional distractor interference in EIB cannot be reduced by load, suggesting the automaticity of emotions and domain specificity of load effects.

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The timecourse of dividing attention: The influence of culture and bilingualism.

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Recent research has shown that focused attention can be divided into two independent foci in about 80ms (Jefferies & Witt, 2019). We know little, however, about the factors that influence the rate of dividing attention. Here we examined the effects of bilingualism and cultural background on the rate of dividing attention. In Experiment 1, the rate of dividing attention was compared in monolingual and bilingual individuals. Bilinguals are known to disengage attention more rapidly than monolinguals (Mishra et al., 2012) and were thus expected to divide attention more rapidly. To assess this, we employed a dual-stream Attentional Blink paradigm with simultaneous distractor streams to the left and right of fixation. One component of the AB, Lag-1 sparing, occurs only if the second of two sequential targets appears at an attended region. Accordingly, we can determine whether attention is unitary or divided by presenting the second target between the streams and assessing whether Lag-1 sparing occurs. The timecourse of dividing attention was assessed by manipulating the stimulus-onset-asynchrony between the targets. The results confirmed that bilingual individuals divide attention more rapidly than monolinguals. In Experiment 2, we compared the rate of dividing attention in individuals raised in East Asian cultures or a Western culture. Cultural background is known to influence whether individuals focus on the global or local details of a scene, and was thus expected to modulate the rate of dividing attention. The results showed that individuals from East Asian cultures divide attention more rapidly than individuals from Western cultures.

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Attentional capture as a function of target and distractor eccentricity

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Visual search is an important part of everyday life. When we are presented with an irrelevant salient distractor, it can capture attention, slowing down search for a target object. This phenomenon has been studied extensively using the additional singleton paradigm. However, in this paradigm search items are typically presented at one and the same eccentricity. Here we were interested to see how attentional capture is influenced by the relative eccentricities of target and distractor. Participants were asked to look for a shape singleton (e.g. a red circle), in a grid of homogeneous nontargets of the same color (e.g. red diamonds). On 75% of trials, one of the nontarget items was replaced by a salient distractor by giving it a different color (e.g. a green diamond). Crucially, target and distractor eccentricities were independently manipulated across three levels of eccentricity (i.e. near, middle, far). In line with previous findings, we show that distractor presence slows down search. Interestingly, we find that while search time increased with increasing target eccentricity, distractor eccentricity had no effect on overall search time, nor did it interact with target eccentricity. At the same time, the proportion of first eye movements towards the target decreased with target eccentricity and increased with distractor eccentricity. However, these factors again did not interact. We discuss the implications for models of attentional capture.

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Discovering boundary conditions of attention state affecting object recognition

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The phenomenon of "seeing less" while attending internal representations is well-known among the general public. However, direct comparisons of internally versus externally directed attention are rare. In this series of studies, we measured the effect of internal versus external attention on the recognition of objects in natural scenes. Perceptual performance was probed while participants directed attention either internally or externally using a dual-task design. An internal attention state was induced by having participants perform a visual working memory task, while an external attention state was induced by having participants monitor whether briefly presented images exhibited mirror symmetry. Half of the trials within each task ended with the object recognition probe while the other half ended with a probe relevant to the respective task types. A study with intervening images between trial start and probe revealed that object recognition (d-prime) was worse during the internal compared to the external attention task. However, a second

study without intervening images showed no effect of attention state. A third study that compared attention state trials with or without intervening images suggests that participants report fewer objects when intervening images are present between trial start and probe, but without an effect of attention state. The mixed results from these studies provoke discussion on how object recognition is affected by attention state. Our preliminary conclusion is that the presence of task-irrelevant intervening stimuli modifies object recognition in attention states.

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The Costs of Overt and Covert Shifts of Attention: A Pupillometry Study

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Attention can be shifted with (overtly) or without an eye movement (covertly). Understanding the biological cost (i.e. mental effort and muscle activity) of attentional shifts will inform how we deploy attention (overtly or covertly) across the external world. Thus far, the cost of overt and covert attentional shifts in comparison to no shifts of attention (control) remain unclear. Pupil size serves as an established marker of mental effort and, potentially, the costs of attentional shifts. In an attention task, observers viewed five placeholder stimuli ('8') at varying eccentricities (-27.5°, -10°, 0°, 10° and 27.5°) along the horizontal plane. An arrow cue indicated which of the placeholders would change into the target ('?' or 'E'). Blockwise, observers had to (i) move their eyes to the cued target location, (ii) maintain fixation but shift their attention to the cued target location (covert), or (iii) keep their gaze and attention central at fixation (control). Our results show that the pupil dilates more during oculomotor planning of overt shifts of attention than covert shifts. This indicates that overt shifts of attention are more effortful and costly than covert shifts. The visual system needs to constantly choose to either overtly or covertly shift attention. The distinct costs of attentional shifts will, in part, determine whether we shift attention overtly or covertly in a given context. Investigating the costs of attentional shifts ultimately contributes to our understanding of how we efficiently process the rich visual world.

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Object-based spread of attention affects fixation duration during free viewing

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Neurophysiological and behavioral studies have revealed that visual attention spreads serially across objects, gradually enhancing neuronal responses and reducing response time to visual probes inside a fixated object (Jeurissen et al., 2016; Pooresmaeili & Roelfsema, 2014). Here, we used data from the Potsdam Scene-Viewing Corpus (Rothkegel et al., 2018) to test if fixation durations of humans reflect this serial spread during a free-viewing task. We extracted saccades' start and endpoints located within the boundaries of objects in the scenes and investigated if various measures of distance between these points predict the fixation duration leading up to the saccade. We reasoned that rapid spread of attention within an object would lead to faster visual processing and, as a consequence, shorter fixation durations. Using generalized linear mixed models, we compared four measures of distance, reflecting different hypotheses of how attention might spread (Jeurissen et al., 2016): (1) Euclidean distance (irrespective of object boundaries), (2) Filling-in distance (inwards from object's boundaries), (3) Pixel-by-pixel distance (the shortest path within the object region), and (4) Growth-cone distance (the shortest path within the object, but depending on the size of homogenous image regions). Among these models, the number of growth-cones between saccade start and endpoints best explained fixation duration within objects (but not outside them). These findings suggest that fixation duration in free viewing is affected by the spread of object-based attention. The growth-cone model may provide a fruitful basis for understanding the dynamics of this selection process.

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The effect of perceived hand location on hand proximity attention

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Visual processing is facilitated around a hand, which is known as hand proximity attention. In this study, we investigated the effects of illusory shift of hand location on the hand proximity attention. Visual probes were presented around a hand using a head mount display (HMD). The participant held a pen type force feedback device (Phantom

omni) by a hand to move the device along a circular path. The pen tip was attached to a ball bearing so the pen movement was restricted to a circular path. While the participant was moving a hand, visual stimuli were presented at various locations along the circular path. Reaction time (RT) was measured at locations with various distance from the hand to show spatial tuning of hand proximity attention. To induce a shift of the perceived hand location, the distance between the visual stimuli and the hand was changed gradually during a 60-second trial. Results showed that RT varied dependently on the distance from the hand, showing a peak at around the hand location at the beginning. After the change of stimulus location, the peak of attention modulation shifted from the hand location to the location of the stimulus that had been at the hand location before the shift. The results suggest that hand proximity attention is not always found at the actual hand location, but at a visual stimulus, which can be a marker of the hand location.

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Poster session 3. Research methods

A Comparison of Equivalent Noise Methods in Investigating Form/Motion Integration

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Static and dynamic cues within certain spatiotemporal proximity are integrated to evoke respective global percepts of form and motion. The limiting factors in such integration are: internal noise, which indexes local orientation/direction detection, and sampling efficiency, which relates to the representation of global orientation/direction. These parameters are quantified using the equivalent noise (EN) paradigm, in which the orientation/direction of individual elements distributes according to a Gaussian distribution around a given mean. EN is commonly implemented with a high and a low noise level. However, when using this simplified version one must assume the shape of the overall noise dependence, as the intermediate points are missing. Here, we investigated whether two distinct EN methods, range-based multisampling and the simplified two-point version, reveal comparable parameter estimates for each of three types of stimuli: Random Dot Kinematograms, static and dynamic translational Glass patterns. The multiple-point EN method employed eight staircases manipulating the mean orientation/direction to track minimum discriminable angle at a given external noise level. The simplified method employed two staircases, one adaptively changing the mean orientation/direction to track minimum discriminable offset in the absence of external noise, and another manipulating the standard deviation to track maximum tolerable noise level at a fixed mean orientation/direction. Model fitting results suggested substantial compatibility between estimates over a wide range of external noise levels sampled with eight data points, and a simplified version producing two highly informative data points. Our findings highlight a practical use of the simplified algorithm to estimate crucial parameters of form/motion integration.

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Modeling of fixation durations during EEG analysis

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A common problem of fixation-related potentials (FRPs) in EEG research is the varying duration of fixations of interest. Often, fixation duration distributions differ between experimental conditions, introducing a potential bias. However, common practice is to average over multiple trials to get an estimate of the underlying brain response, thus disregarding the problem of varying (fixation) durations. In the worst case, this can lead to biased or even non-sensical inferences about the nature of the brain. Furthermore, the varying fixation durations usually co-occur with temporal overlap of different FRPs adding further bias. We applied regression methods to simulated and real-world data to systematically explore how fixation duration affects the resulting FRPs and how to adequately model them. To account for the temporal overlap, we used deconvolution-based overlap correction as implemented in the unfold-toolbox (https://www.unfoldtoolbox.org/) and investigated its additional influence on the FRP estimation. We find that modelling fixation durations as binned or linear predictors performs poorly. However, non-linear effects using spline-regression seem to be able to capture the main patterns and are thus a promising candidate for further study.

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Measuring unconscious visual perception

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Continuous Flash Suppression (CFS) is a popular tool in the study of pre-conscious visual processing. Differences in the time it takes to break the suppression are generally taken as evidence for differences in unaware processing of stimuli. However, it is unclear what really marks the point of breakthrough, at which a stimulus arrives in the domain of conscious perception.

Here, we used EEG/SSVP (frequency tagging) in an otherwise standard CFS breaking paradigm. While the masking in CFS generally is already tagged with a frequency equal to the mask refresh rate, target stimuli are typically faded in gradually by means of a contrast ramp to avoid spontaneous break-through at the time of appearance. We modulated the gradual contrast ramp of the target with a tagging frequency of its own, allowing for a measurement of oscillatory power in the spectrum of the recorded EEG. Indeed, we found the oscillatory power of the target stimulus to increase with increasing target contrast and time, while at the same time the power of the masking frequency was diminished, despite the absence of contrast changes of the masking stimulus.

These findings may point the way towards an objective estimate of target break-through time independently of the participants response, circumventing bias and response criteria that would otherwise contaminate conventional response time measures.

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Vernier acuity and its interplay with reading in (pre)school children—a multimethod online approach

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Vision is crucial for many tasks and needed to acquire skills such as reading. Many visual abilities still develop throughout and beyond infancy and childhood. Among those is Vernier acuity, a basic visual function that relies on cortical processing. Strikingly, Vernier acuity increases around the start of school and we hypothesize that reading acquisition (further) drives this development. To investigate this, we chose a behavioral and electrophysiological approach. Due to the Covid-19 pandemic, we started with an online/remote pilot investigation assessing Vernier acuity and reading skills. To disentangle the effect of reading acquisition, we used a longitudinal design with same-aged children (N=37), who have different school entry dates. Results show that Vernier thresholds in the computer-based Freiburg Visual Acuity Test (FrACT) and our custom-made paper-pencil-task were comparable. Also, the children showed age-appropriate reading performance. Nevertheless, some families did not complete all tasks or had problems with the procedure. Preliminary FrACT results show a significant improvement in Vernier thresholds after one year ($F(1,17)=10.58$, $p=.005$), which is not group (reading/non-reading) specific ($F(1,17)= 0.51$; $p=.487$). Preliminary results found no relationship between Vernier acuity and reading skills ($R=0.099$, $p=.74$). We conclude that online/remote measures might be a valuable methodological approach to studying the development of vision and its relationship with reading. Also, the paper pencil task might be an easy to use approximate measurement of Vernier acuity. However, a lab-controlled procedure including electrophysiological measures in a larger sample might be more sensitive to reveal the development of Vernier acuity and its relationship with reading.

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DOS: a parameter-free model-free adaptive procedure to quantify perception

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The 'quantification' of perception is arguably both one of the most important, and one of the most difficult, aspect of perception study.

While this is particularly true in visual perception, in which the evaluation of the perceptual threshold is a pillar of the experimental process, this complex problem is at the heart of experimental psychophysics, and is underlying many neuroscience studies.

This work proposes a new adaptive procedure to solve this problem, named Dichotomous Optimistic Search (DOS), based on recent advances in black-box hierarchical optimization. Compared to existing approaches, DOS is completely parameter free and model-free. This entails multiple advantages: contrarily to existing Bayesian methods, DOS does not require the a priori choice of a family of function (e.g. Gaussian), preventing costly mistakes in the experimental process. Moreover, DOS internal parameters are self-tuned, thus do not need to be manually chosen using heuristics (eg. step size in the Staircase method), preventing further errors.

Furthermore, DOS is based on state of the art optimization theory, providing strong mathematical guarantees that are missing from many of its alternative.

Empirical evaluations of DOS showed that it is at worse comparable to its alternatives, and at best orders of magnitude better. In particular, DOS rapidly outshines them

when the parameters or the model function are not perfectly chosen, or when the stimuli budget is larger than a hundred.

Given these advantages and its ease of use, we argue that DOS can improve the process of many psychophysics experiments.

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EEG Source Localisation Using esinet, an Artificial Neural Networks-based Method

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Magneto- and Electroencephalography (M/EEG) are non-invasive methods used frequently for neuroscientific research and clinical diagnostics. These brain imaging methods provide measurements of high temporal but low spatial resolution. To investigate spatial dynamics of the M/EEG, namely finding the neural sources that give rise to the recorded signal, the inverse problem must be solved. The inverse problem is ill-posed, meaning that various combinations of neural sources can result in the same distribution of M/EEG activity.

We recently developed a novel machine-learning-based source localisation method using different artificial neural network (ANN) architectures that showed higher performance compared to classical approaches. Specifically, a long short-term memory (LSTM) network performed best due to the incorporation of spatiotemporal information.

So far, we evaluated the ANN-based approaches using simulated and real M/EEG of a median nerve stimulation paradigm. Further evaluation is required to qualify the approaches for the deployment into research and clinical contexts. In this work, we apply the ANN-based approaches to data from epilepsy patients who underwent single-pulse electrical stimulations (SPES), which is a semi-synthetic EEG data set with known ground truth sources. Furthermore, data from healthy participants who observed faces will be used and results compared among different inverse solutions and matched with neural sources described in the literature.

Given the performance of our novel source localisation methods, we are convinced that they are appropriate and easy-to-apply inverse solutions to be considered in future source localisation studies, both in clinical applications and basic research.

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The Forest Predicts The Tree: Investigating Spatial Predictive Context with Rapid Invisible Frequency Tagging (RIFT)

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The brain exploits statistical regularities, or predictive context, to guide our perception. Within visual search, spatial predictive context, learned outside of awareness, can improve behavioral performance, also known as contextual cueing.

Here, we set out to investigate how predictive context modulates neural processing of target and distractors during visual search, leveraging Rapid Invisible Frequency Tagging (RIFT) and Magnetoencephalography (MEG). We tagged target and distractor stimuli with different frequencies within visual search scenes that were either new (unpredictable) or repeated every block (predictable).

Preliminary results show that we can successfully entrain multiple frequencies simultaneously, showing the potential of RIFT as a successful method for tracking visual processing of competing stimuli.

For general visual search during new trials we see increased power at the target frequency compared to the distractors. Moreover, during old trials, when context becomes

predictive, we see additional target enhancement. Interestingly we also see a clear enhancement of distractors, even when they are far away from the target indicating that indeed the context is playing a greater role in these scenes. We also see some yet to be explored signs of suppression of distractors close to the target, which might be a feature of the attentional field.

Together, these results reveal the global nature of spatial predictive context: the forest is predicts the tree.

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AIM+(Angular Indication Measurement Plus) enables rapid and self-administered assessment of visual perception dependency across multiple stimulus dimensions

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Vision diagnostics are critical in basic and clinical science, but current approaches have several shortcomings (time-consuming tests with predefined stimuli that are inaccurate, imprecise and are administered and analyzed by trained staff. In many cases, visual function depends on multiple stimulus properties (e.g. spatial or temporal frequency and contrast) that are too time-consuming to measure comprehensively. We developed AIM+, a generalizable, multi-dimensional search method that enables rapid, adaptive, and self-administered assessment of visual function across multiple dimensions.

We applied AIM+ to interrogate the contrast-sensitivity functions (CSFs) of eight typically-sighted and two atypical adults. Three charts of 4*4cells contained Gaussian-windowed sinusoidal gratings of adaptively-controlled spatial frequency, contrast, and orientation. Observers reported the orientation of each grating via mouse click. Orientation identification thresholds were estimated with a gaussian function fit to the difference between true and reported target orientations. Analysis-of-Variance(ANOVA) and planned comparisons compared area-under-the-CSF(AUC), CSFAcuity, and test durations between OS, OD, OU.

The median duration of AIM+ CSF assessment was 109sec±10.7/eye. AUC and acuity estimated with AIM+ CSF were not significantly different between eyes but were elevated for OU compared to OS&OD. Interocular difference and overall reduction of AUC and CSF-Acuity were detected in one amblyopic observer and one Ortho-K contact lens wearer, respectively.

AIM+ is a self-administered and rapid approach that can be applied to multi- dimensional sensory functions (e.g. spatio-temporal CSF, threshold versus contrast, equivalent noise). Here, we validate AIM+ for measurement of the full CSF in under 2 minutes.

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Visual image and category information in monkey EEG and human MEG

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Multivariate decoding techniques in combination with EEG and MEG have opened a non-invasive window onto the neural processing of natural images and visual categories. However, it remains unclear which features drive category decoding. Furthermore, it remains difficult to link human M/EEG findings to underlying circuit mechanisms as studied invasively in monkeys. To address this, we recorded human-comparable EEG in macaque monkeys and human MEG using the same stimulus set. We systematically modified low-level features (spectral power, spatial arrangement) and high-level features (Gestalt) of natural images to disentangle their contribution to image and category decoding. We found that image and category information could be robustly decoded in both, monkey EEG and human MEG. Furthermore, in both species, category information was dependent on global shape integrity rather than on low-level features such as spectral power and spatial arrangement. Our results suggest that global shape is critical for visual category processing in humans and monkeys. Furthermore, our findings highlight monkey EEG as a valuable tool to bridge the gap between human and monkey electrophysiology.

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Poster session 4. Shape Perception

Human responses to the relationships between object shapes and moving directions

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The inverted triangle is an eye-catching shape and is often used in traffic signs. As the word "inverted" suggests, its unstable shape is thought to call attention. However, while an inverted triangle gives such an impression when it is not moving, the sense of stability/instability may change when the inverted triangle is moving. This study conducted experiments in which stable and inverted triangles moving upward and downward were presented on the screen, and respondents caught the moving figures with the mouse cursor. Through these experiments, we found that subjects were able to capture more accurately when the direction of the triangle matched the direction of movement (stable triangles moving downward and inverted ones moving upward) than when the direction did not match.

This effect is considered a type of stimulus-response (S-R) compatibility. It is the effect that a response to a stimulus is faster and more accurate when the properties of the stimulus and response are compatible than when they are not, and it has been studied for many years.

In the present experiment, the stimulus has a direction, but the response does not. However, to match the mouse cursor to a moving figure and click, the respondents must follow the direction of the movement and react accordingly. Thus the effect of stimulus-response compatibility emerges. Based on the results of this experiment, it seems that the visual impact of inverted triangles should be employed in consideration of the direction of motion.

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Perception of natural object shape deteriorates with increasing cognitive load

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Object manipulation requires dexterous movements of the hands; from this, we extract the percept of haptic shape. Manual dexterity is linked to attentional control of the motor system. However, there is still a lack of understanding how haptic shape perception is modulated by attentional processes. The current investigation evaluated the effect of attentional load during object exploration on haptic shape perception. We used an established natural object set (i.e. replicas of bell peppers) to assess haptic shape discrimination. A total of forty participants (31 females, 18-36 years) took part in our study. The shape discrimination task comprised 96 trials in which participants explored two bell pepper replicas consecutively. After each trial they had to indicate whether the shape of both bell peppers was 'same' or 'different'. Discrimination performance was quantified by deriving d' as a sensitivity measure. Each shape discrimination judgment was made with or without concurrent attentional load. Additional attentional load was introduced by asking to memorize a set of digits. Length of the presented digits spans was chosen adaptive depending on the individual memory performance. Order of task conditions was counterbalanced across participants. We found that manual dexterity was highly correlated with individual cognitive control resources, but did not predict haptic shape sensitivity. Most importantly, our data showed that haptic shape perception was significantly reduced when participants' attentional resources were challenged by the additional task. We suggest that our findings indicate a dissociation between exploratory behavior itself and the ability to perceive haptic shape.

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Introspective visual experience in shape recognition near the acuity threshold

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Shape recognition is a crucial every-day task and assessed in standard acuity testing, thus underlying the legal definition of visual disability (besides other criteria). However, the corresponding psychophysical threshold is not necessarily representative of the stimulus sizes required for adequate real-life performance, where sufficient recognition confidence and visual satisfaction are required. For instance, newspapers text cannot be read fluently at threshold size. In 20 normally-sighted participants, we systematically assessed peri-threshold decision confidence and visual satisfaction. Landolt Cs at multiple sizes around the recognition threshold (≙ acuity) were displayed. In the first experiment, participants judged after each stimulus presentation either the optotype orientation, their own decision confidence, or their visual satisfaction (the latter two on a 4-point Likert-type scale) in separate runs. In the second experiment, responses for both orientation and confidence were obtained for each individual stimulus presentation. Psychometric functions for recognition correctness, confidence, and satisfaction were computed, yielding threshold and slope values. Compared to the recognition task, thresholds were 20% and 70% higher for confidence and satisfaction, respectively. Recognition took longer at threshold compared to both sub- and suprathreshold sizes, confirming previous findings. Slopes for recognition and confidence were mostly congruent, possibly reflecting similar sources of trial-by-trial variability. The data lays the foundation for a prospective approach to quantifying the impact of visual impairments by assessing the introspective visual experience with psychophysical rigorousness. We expect confidence and satisfaction to depend differentially on the perceptual impact of specific visual impairments, thus providing a more realistic measure of disability.

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Local & Non-Local Factors in Perceptual Shape Completion

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Humans are known to rely profoundly on bounding contours for object detection, segmentation and recognition. This task is complicated by the interposition of other objects in the visual field that lead to occlusion: partial blocking of one object by another. However, the impact of occlusion on human perception is mitigated by the human ability to perceptually complete partially occluded bounding contours, i.e., to fill-in the missing shape information. Here we examine the degree to which the human

brain uses local and non-local cues to solve this perceptual completion task. Each visual stimulus consisted of a sequence of dots regularly sampling the outline of a 2D shape. To simulate occlusion, a contiguous interval of 10-50% of the dot pattern was extinguished. Observers were asked to adjust a probe dot along a linear axis orthogonal to the gap until the dot appeared to lie where the contour would be, were it visible. Two classes of shape were employed: animal shapes, which afford both local and global cues to completion, and metamer shapes, which match the curvature statistics of the animal shapes but are otherwise random, thus affording local but not global cues to completion. Mean absolute error was lower for animal shapes than for metamer shapes and, while completions tended to be negatively (inward) biased for both, the bias was less for animals than metamers. Together these findings point to a contribution of non-local shape cues to perceptual contour completion.

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Source Reconstruction of the ERP Uncertainty Effects reveals common Neural Mechanisms for different Stimulus Categories

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During the observation of an ambiguous figure, our perception becomes unstable and alternates repeatedly between mutually exclusive interpretations. Recent studies compared the EEG evoked by ambiguous / low-visibility stimuli and disambiguated / high-visibility stimulus variants and found large amplitude differences at two ERPs (event related potentials): An anterior P200, 200 ms after stimulus onset and a posterior P400, 200 ms later with larger amplitudes for low ambiguity and high visibility stimuli ("ERP Uncertainty Effects"). The high similarity of effects across very different stimuli categories (e.g., geometry, motion, and gestalt, letter/number embedded in noise), indicates resolution of uncertainty at an abstract level of perceptual processing.

In the present study we investigated whether the highly similar spatio-temporal patterns of the ERP Uncertainty Effects originate from the same neural sources using EEG inverse solutions based on artificial neural networks.

Source analyses of the P200 and P400 reveal a shared subset of neural generators in the P400 time window in various regions. Our findings indicate common processing units of uncertainty resolution during perceptual decision making across stimulus categories.

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Spatial and temporal summation drive the perception of complex Glass patterns

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Human vision relies on continuous integration of form signals and motion when processing information from the environment. This integration process can be investigated using dynamic Glass patterns (GPs), a class of visual stimuli that combines form and motion cues. Different percepts of global form can be induced by varying the orientation of the pairs of dots (dipoles) composing the GPs. Dynamic GPs induce the perception of apparent non-directional motion and are made of a rapid succession of unique frames, each composed by a static GP. Previous psychophysical research showed that both the number of unique frames and the pattern update rate affect discrimination performance for translational and circular dynamic GPs. In this study, we used different types of complex dynamic GPs (circular, radial, and spiral) and assessed whether discrimination thresholds for complex patterns rely on both number of unique frames and pattern update rate. Participants had to discriminate which of two temporal intervals contained the most coherent dynamic GP. Dynamic GPs varied in terms of update rate (i.e., temporal frequency of the pattern) and number of unique frames composing the sequence. The results indicate that circular GPs are more easily detected than radial and spiral patterns, showing lower discrimination thresholds. Furthermore, we confirmed that complex GPs rely on both number of unique frames and pattern update rate, suggesting the coexistence of two mechanisms: spatial summation of form signals from unique frames and temporal integration of local motion signals determined by the pattern update rate.

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Poster session 5. Perception & Action – I

Biased Representation of Body Postures

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Body postures provide information about others' actions, intentions, and emotional states. Little is known about how postures are visually represented. Here, we hypothesized that internal visuo-motor knowledge biases the representation of perceived body postures, considering two natural constraints: (1) Default postural state - the body state when no force is applied against gravity, for example when we stand still; and (2) biomechanical constraints - the range of possible movements intrinsic to the human body. The first principle predicts that lifted limbs will be represented by the observer as lower, towards their default position. The second principle predicts that the representation of a nearly impossible posture (e.g., an arm far behind the head) will be biased towards the nearest possible posture. We tested these predictions using a posture change detection task, in which participants had to identify a change between two sequentially presented arm postures. Biases in posture representation were indexed by the difference in detection performance between upward and downward changes. Across four arm positions, we observed that detecting upward posture changes was generally easier than downward, implying that the first arm posture was represented as lower, i.e., towards a default postural state. Interestingly, consistent with predictions from biomechanical constraints, this bias was smaller for upper arm postures far behind the body than in front of the body, and larger for lower arm postures far behind the body than in front of the body. Altogether, these findings indicate that top-down visuo-motor knowledge shapes the visual representation of body postures.

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Measuring complex interactions between hands and objects during visually-guided multi-digit grasping

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When we grasp an object, we need to adjust our hand pose to the object's shape and select appropriate surface contact regions for our hand to establish a stable grip. How we select contact points has previously been studied by projecting markers attached to the fingertips onto the object. However, this approach does not allow measuring complex interactions between the hand and the object, e.g., when extended regions of the finger or palm are in contact with the object's surface. Here, we propose a workflow to estimate full contact regions from marker-based tracking data. Participants reach and grasp real objects while the 3D positions of markers attached to both the objects and selected locations on the back of the hand are being tracked. From the hand markers, we then derive hand joint poses and positions, and use a state-of-the-art hand mesh reconstruction algorithm to generate a mesh model of the participant's hand in the current pose and position. Using 3D printed objects realized from object meshes allows us to co-register hand and object meshes, and to estimate contact regions from intersections between meshes. We validate the approach by comparing the reconstructed hand meshes with video data synchronized to the motion capture. Finally, we provide proof-of-concept demonstrations of some of the kinds of studies into visually-guided grasping that can be realized using our approach.

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Linking the time course of visual feature coding to behaviour

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The basic computations performed in the human primary visual cortex have been the subject of a large body of research. Recent work using neuroimaging methods with high temporal resolution has investigated how feature combinations share common neural processing mechanisms, and at what time point in the response they can be processed independently from one another. However, we do not yet know how differences in neural feature coding relate to behavioural judgements of the stimulus similarity, and whether such perceptual judgements are biased towards certain features. In this study, we first measured neural responses using electroencephalography (n=16) to a large set of 256 oriented gratings that varied in orientation, spatial frequency, luminance, and colour, to map the response profiles including the timing and strength of the neural coding of basic visual features. We then related these to independently obtained behavioural judgements of stimulus similarity. The results reveal how the temporal response profiles of basic visual features relate to behavioural judgements of perceptual similarity.

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Examining sense of agency in the jittery temporal interval between gaze shift and visual feedback using gaze-contingent multiresolution display

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Sense of agency (SOA) has been found to be weakened in temporal action-effect interval experiments, where manipulated temporal delay between user's action and visual display update. However, SOA has been scarcely investigated in 'jittery' temporal delay (I.e., inconsistent delay with deviation). While human-computer interaction has been utilized in communication via internet, the interval has not maintained constant, rather, has distribution.

Here, we adopted jittery temporal delay for the gaze-contingent multiresolutional displays, rendering high-resolution and low-resolution images in the user's central vision and peripheral areas, respectively. Participant's task was a simple visual search for Chinese characters while a single-letter-sized gaze-contingent window had presented. Relative temporal delay between eye movement and the window was set to truncated normal distribution with range; μ to $\mu+2\sigma$. σ was fixed to 50 across conditions while μ varied from 0 to 400 ms. As non-control condition, recorded gaze was presented.

Subjective SOA scores and calculated controllability scores of the window decreased as the temporal delay increased. SOA score was exceeded by sense of delay score where μ was 150 ms and lowest above where μ was 300 ms. Distribution of fixation duration varied at μ from 100 to 400 ms, similar to distributions at constant delay.

The results were almost consistent with previous study adopted eye movement as well as hand movements with constant temporal delay, suggesting similar mechanism has underlie. Meanwhile, jitter didn't affect subjective SOA. Further experiment should be conducted to investigate whether inappropriate task design or μ and σ lead to these results.

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Guiding a cursor to a target: frame rates and delays

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An important issue in human visuo-motor control is having to deal with visuomotor delays of at least 100 ms. When moving a computer mouse to guide a cursor to a target on a screen, there is an additional delay between mouse and cursor of up to 50 ms. Using a screen with a high frame rate can reduce this additional delay. Does reducing the additional delay influence goal-directed movements, given that people also have haptic information about their movements and that they rapidly adapt to visuo-motor delays? To find out, we had participants move a cursor to consecutive targets as quickly as they could. We varied both the delay between mouse and cursor, and the frame rate of the monitor. The time it took participants to move the cursor to the target increased with the delay, but not with the interval between frames. Decreasing how often the cursor was shown without changing the actual frame rate of the monitor did systematically increase the time taken to reach the target. Reducing the cursor's contrast also increased the time taken to reach the target, but not enough to account for the effect of increasing the interval between cursor presentations. Thus, both the continuous presence of information with which to adjust the movement and the delay with which such information is provided appear to influence performance. Despite all this, only seeing the cursor 13 times was enough to guide it to the target when the cursor was presented every 50 ms (20 Hz).

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The Effect of Color Cues on Eye-Hand Coordination Training

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Color is affective on motor activities and learning. In this study, we evaluated the effect of color cues on individuals' hand-eye coordination and learning abilities via a mirror-drawing test. We created a task setup using artificial daylight mode with a color temperature of 6500 Kelvin in a color viewing box located in a dark room. Participants were instructed to draw a star shape inside of 3millimeter-guides. We also placed a card box in front of them allowing to see their hands through a mirror but not directly their hand. Further, we changed the outline color of the star shapes to red, blue, and green. In total, six participants performed the task with four repetitions. For each repetition, the participants' task execution time and their error rate were measured. The results showed that the shortest task completion time was green with 30.01 milliseconds and the longest task completion time was in red with 37.10 milliseconds. We also determined that the error rate was 43.75% higher for blue and 26.56% lower for green compared to red. In line with the data obtained, it has been determined that there is a significant relationship between the use of color and the hand-eye coordination, and learning abilities of individuals. We hope that our results presented in

this study guide researchers, designers and engineers working with visual cues.

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Effects of visual–motor synchronicity between the avatar and self on remapping of peripersonal space

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Multisensory integration (visual-tactile or audio-tactile) is facilitated in the space closely surrounding the body, termed peripersonal space (PPS). PPS is not necessarily fixed to physical body but has been suggested to be associated with bodily self-consciousness; for example, when illusory body ownership occurs to the virtual avatar in front of participants (i.e., full body illusion [FBI]), the PPS boundaries shift toward the avatar (Noel et al., 2015). However, it is not yet known whether remapping of PPS between one's own and virtual avatar, rather than a shift (or expansion) of PPS of one's own, during FBI, is elicited. To elucidate this point, this study investigated whether the visual-tactile facilitation effect as an index of PPS occurred when a visual stimulus approached an avatar but did not approach one's own physical body. Participants observed the virtual avatar which moved synchronously with the participant's movements from the side in the third-person perspective. Then, they responded as fast as possible to tactile stimulation presented on their chest, while an external visual stimulus was presented as approaching the avatar. The visuo-motor synchronized avatar was compared with the asynchronized avatar and the static cuboid. We found that sense of body ownership and agency were stronger in the synchronized avatar than the other conditions, but there was no difference of the visual-tactile facilitation effect in the avatar conditions. This suggests that the subjective feeling of the body ownership to the avatar may not be sufficient to elicit the remapping of PPS.

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Visual and haptic control of grasping changes in the object proximity

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By investigating the role of haptics and vision in multisensory grasping, we have demonstrated that haptics is a valuable source of information we rely on to sense specific object properties. Here we have re-analyzed over 5000 movements from these previous experiments to investigate several novel features of grasping performance under visual (seeing the object), haptic (feeling the object's properties with the contralateral hand without seeing it), and visuo-haptic (seeing and feeling the object) conditions. Specifically, we explored the joint evolution of the grip aperture and hand velocity during the final approach trajectory before object contact. When the hand was relatively far from the object, we observed the classic advantage of multisensory over unisensory conditions and the advantage of vision over haptics. Instead, the advantage of vision faded away in object proximity. Here, the haptic condition showed the major advantages with smaller grip apertures than in the visual and visuo-haptic conditions and faster movements than in the visual condition. This was coupled with a smoother closure of the grip aperture in haptic compared to the visual and visuo-haptic conditions. These results show that the low latency positional information of the contralateral hand is more efficient than the online visual feedback for the final grip aperture adjustments. However, we observed that visuo-haptically guided grasping was also influenced by vision despite its efficiency being lower than in haptics. Our findings suggest that the contributions of vision and haptics are flexibly adapted along with the different phases of multisensory grasping movements.

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Continuous tracking as a probe for perceptual motion extrapolation

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Humans are highly proficient in interacting with dynamic, moving objects when navigating the environment and performing tasks like driving or playing sports. This requires the ability to extrapolate trends and trajectories from moving targets, and to anticipate where an object will be based on evidence from its behavior in the recent past. Continuous psychophysics offers convenient tools for investigating these dynamic tasks. In this work, we explore the performance of human volunteers in a visuo-motor task requiring continuous tracking of a trajectory of drifting dots which erratically changed in elevation following a random walk. We varied both the amount, temporal proximity and reliability of prior information to be used in the tracking task by limiting the participants' view of the dots' trajectory, by only showing an anticipated preview window of the

trajectory and by introducing spatial discontinuities on the dots path, respectively. We show that when providing ample and reliable prior information about how the dots will move, the participants exhibit excellent tracking performance; the highest performance benefits arise when providing perceptual evidence in a preview window presented 250 ms before time of contact; observers can flexibly buffer information presented up to 800 ms before the actual time of contact of the trajectory; tracking lag arises from impairments in the ability to internalize the spatial structure of the dots' path. In conclusion, this work shows that tracking is a viable tool to characterize the action-perception loop, which is remarkably flexible and can adapt to the quality of available perceptual information.

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The impact of visual discomfort of floor patterns on human gait kinematics

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Visual patterns which deviate from the statistical properties of natural scenes result in inefficient processing in the visual cortex, causing visual discomfort. In particular, high-contrast, square-wave grating patterns produce the strongest perceived visual discomfort. This effect is most pronounced when gratings are around three cycles-per-degree of visual angle (cpd). Many patterns fitting this description can be seen in the urban environment. However, to date, there appears to be no investigation which examines whether such patterns, when present on the floor, affect the fundamental characteristics of human gait.

Here, participants (n = 20) were asked to walk over high-contrast, square-wave grating patterns projected onto the floor, and to subjectively rate each pattern for visual discomfort. The cpd was parametrically varied (1.0, 0.5, 0.25, 0.125, 0.0625, 0.03125 cpd) trial-by-trial in random order. Gratings between 1.0 and 0.125 cpd led to a reduction in velocity and step length, and an increase in step time, in comparison to 0.0625 cpd gratings and a medium-luminance, grey control floor. Furthermore, subjective ratings of visual discomfort were negatively correlated with changes in velocity and step length, providing a predictive power of ~11%.

We discuss the impact of spatial frequency of floor patterns with regard to visual discomfort, perceptual load, and the consequences this has for the fundamental characteristics of human gait. Moreover, we will consider the implications this might have for accessibility and future urban design.

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Poster session 6. Eye movements – I

What you see affects where you look next: Current foveal inspection and previous peripheral preview influence the when and where of subsequent eye movement decisions

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Humans visually inspect the world with their fovea and select new parts of the scene using saccadic eye movements. Foveal inspection and the decision of where and when to look next proceed simultaneously, but there is mixed evidence concerning their independence. Here, we tested the interdependence of foveal inspection and peripheral selection using drift-diffusion modelling. Participants first made a saccade to a predetermined inspection target. The inspection target was either a face or a visual noise patch and it could either be peripherally previewed or only the target's outline was shown in the periphery. As soon as gaze was shifted to the inspection target, two selection targets appeared in the periphery, one face and one noise patch. We measured the saccadic decision and the fixation duration on the inspection target. We found that the inspected target's meaningfulness and the opportunity to preview it peripherally affects fixation durations as well as the upcoming saccadic selection. Drift-diffusion modelling showed that meaningfulness and the absence of peripheral preview can both delay the subsequent saccadic decision process and affect the rate at which peripheral information is accumulated. Our results thus show that foveal inspection and the decision about where and when to look next are dependent on each other and that peripheral information can be maintained across the saccade to influence subsequent eye movement decisions.

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Where do we look when walking on stairs in the real world

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We often encounter stairs during our daily life. Gaze is usually directed at items that are critical for the task at hand, and knowing the precise locations of the steps is critical for navigating a staircase. However, it is not evident that one must look at each step before stepping on it and there may be reasons to look elsewhere. We explored gaze behaviour when walking up or down a staircase during a navigation task in a familiar environment. Participants were not aware that stair climbing was the focus of investigation. We found that participants often looked at each step sequentially. However, on average they only directed their gaze at slightly more than half the steps, with the first step regularly being skipped when ascending. When approaching a staircase to a higher floor, gaze was consistently directed above the edge of the first step. Since the participants did not stumble they must have used information from their lower visual field to effectively transition from the ground surface to the staircase. When approaching a descending staircase gaze was directed close to the edge of the first step. By employing a variety of staircases in different uncontrolled environments, with participants not being aware that staircases were of particular interest to us, we probably obtained a description of gaze behaviour that is closer to that used in daily life than earlier studies in which the focus was explicitly and exclusively directed at the staircase.

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How infants use their parent's nonverbal behavior to anticipate turns in conversation

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Background: Before children learn to speak, they already make anticipatory looks to an upcoming speaker in conversation. Here, we investigated what visual information in the nonverbal behavior of parents might influence infants' ability to predict and follow turns in conversation.

Methods: We had 15 parent-infant (aged 6-12 months) dyads interact in a live dual eye-tracking setup. The parents were asked to perform a staged conversation with two hand puppets under two instructions: (1) while always looking at the speaking puppet and (2) while always looking at their child.

Results: Infants looked more at the speaking puppet than the non-speaking puppet, and this was more pronounced when parents were instructed to look at the speaking puppet than when they were instructed to look at their child. Moreover, infants did not look more at the face of the parent when the parent looked at them.

Conclusion: We conclude that infants use the orientation of their parent's face as a source of visual information for following turns in conversation. Thus, parents' nonverbal behavior may help infants navigate social interactions.

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Oculomotor routines for perceptual judgements

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Yarbus' work has previously shown that gaze patterns depend on a given cognitive task. In everyday life we often make simpler visual judgments about properties of objects, e.g., how heavy is a certain object, or will it fit into a specific place? Our goal in the present study is to establish a methodology for quantifying whether there are also task specific oculomotor routines for perceptual judgments. Observers saw different scenes presented in a naturalistic environment in photorealistic virtual reality. Each scene presented two objects on a table. On half the trials, one of the two objects was shown on top of a box (which elevated the object vertically). Observers were asked to make judgments about which of the two objects was taller, wider, or brighter while their gaze was tracked. As all tasks were performed with the same set of virtual objects in the same scenes, we can compare spatial characteristics of explorative gaze behavior to quantify oculomotor routines for each task. Width and brightness judgments showed fixations around the center of the object, but the width task showed a larger horizontal spread. When asked to judge the height of the object, gaze was shifted towards the top of the object. Especially when both objects were presented on the table, gaze shifted mainly between the two top corners that were closest to each other. Our results suggest there are differences in gaze behavior across tasks, and those routines presumably help to inform perceptual judgments.

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Saccade kinematics reflect object-based attention in realistic but not in simplified stimuli

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Object-based attention effects are often explored with adaptations of the classical two-rectangles paradigm (Egly et al., 1994). Participants respond faster to a probe presented within a cued object than to a probe presented equidistantly within a different object. This response-time advantage is one of the most common behavioral measures of object-based attention, but it is hard to transfer to real-world scenarios and exploration behavior. In search of measures that allow for testing object-based selection in realistic scenarios, we designed two adaptations of the two-rectangle paradigm and investigated whether the kinematics of saccades executed across these objects reflect object-based selection. In both experimental adaptations, we used a double-saccade task: The first saccade target was instructed by a central cue pointing to one of the ends of an object; the second saccade was always directed to a neighboring target location, either in a clockwise or counterclockwise direction. The dependent variables were parameters of the second saccades, half of which were executed within the object, while the other half targeted a different object. We found a significant object-based effect on saccade kinematics: Within the same object, latencies were shorter, landing positions more accurate, and peak velocity higher. However, these effects were limited to stimuli with clearly distinguishable object features: Previous object motion history, realistic textures, colored outlines, and uneven polygon shapes. With a simplified two-rectangle design, saccades did not reveal same-object effects. We will discuss the benefits of enriched experimental displays for measuring object-based selection using alternative measures such as visual sensitivity.

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Cross-cultural differences in strategies of complex images visual search

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This paper compares the features of the visual search for the target symbolic image in the cross-cultural perspective using eye movements analysis. The subjects were introduced to a target stimulus (a website icon), which they were then to find in a 9x9 matrix filled with similar images. The matrix was shown 32 times, each time with new images. The study involved two groups: Russian students (n=26); Azerbaijani students (n=24). The search time for the target stimulus and the indices of the subjects' eye movements were recorded with the SMI Gaze & Eye-tracking System. Differences in the search time were insignificant, although the Russian sample was somewhat faster. Differences in the oculomotor activity were highly significant ($p<0.001$). The search in the Azerbaijani sample featured shorter fixations (198.8 vs 260.6 ms), and higher amplitude (4.9 vs 3.1 deg) and high-speed saccades (126.8 vs 93.5 deg/s) compared to the subjects from the Russian sample. A possible interpretation is that representatives of Azerbaijani culture tend to use the ambient mode of visual processing, while representatives of Russian culture rely more on the focal mode of visual processing. The ambient mode provides a wider coverage of the space or context of the search. The focal processing mode allows one to focus more on individual objects. In general, the results obtained are within the framework of the R.Nisbett and T.Masuda (2007) model, which describes differences in the perception and interpretation of information in different types of culture. [The research is supported by RFBR project # 20-013-00674]

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Investigating non-verbal bids of attention with a virtual human: an online study of gaze.

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A key to building social relationships is the alignment of mental representations through joint attention, but the details are poorly understood. We investigated the role of eye-contact and collaborative gaze between real and virtual (VH) humans in a series of seven online experiments. Our task required participants to work with a VH to complete two puzzles. On each trial, a puzzle piece, hidden from the participant, was presented to the VH and the participant observed the VH's gaze behaviour derived from human recordings. In a 2x2 design for (i) collaboration and (ii) eye-contact, this behaviour (i) either directed the participant's attention to which of the puzzle boards the piece belonged or was uninformative, and (ii) either did or did not involve eye-contact. Participants responded to these behaviours as quickly and accurately as possible by indicating to which board they were being directed. In experiments 1-4, VH speed and construction (with or without body) were manipulated but had no effect on the general pattern of results. Later experiments (5-7), aimed to address limitations by increasing trial numbers, using computer-controlled gaze, and re-defining the sequences. For the data collected (1-4), responses were faster and more accurate for collaborative trials, but slower for eye-contact revealing an unexpected aftereffect of time-consuming cognitive

resource for this factor. Overall, our paradigm has focused on the role of eye-gaze in order to improve our understanding of its role in joint attention and subsequently, social relationships.

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The adaptability of the Functional Field of View to task difficulty in a gaze-contingent search paradigm: a registered abstract

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The functional field of view (FFV) is a limit on the region of visual information around the current gaze position that can be effectively processed during a fixation. The size of the FFV is adaptable and is determined by retinotopic (physiological) and functional (cognitive) factors. Changes in the FFV may also reflect the difficulty of the given task, shrinking in response to high task demands and expanding during easier tasks. Based on our previous pilot visual search experiment, we propose a registered abstract to investigate the dynamics of FFV adaptability using a gaze-contingent search task. Using the gaze-contingent search paradigm, we expect to manipulate the FFV in a controlled fashion. Our participants (N=15) will search for either an upright (easy condition) or an upside-down target (difficult condition) among a set of distractors through three aperture sizes (small, medium-sized and large) that would allow us to additionally manipulate task difficulty. We plan to conduct analyses of response times and accuracies in each of the difficulty conditions given all aperture sizes using a repeated measures ANOVA, as well as the interactions between them. A general effect we expect to observe is deteriorating performance in response to the increase of the search difficulty conditions. Data collection is planned for May-June 2022.

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Using individual differences to understand saccade-pursuit interactions

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During natural behavior saccadic and pursuit eye movements occur together to allow optimal tracking of dynamic scenes, however the way people use combinations of saccadic and pursuit eye movements differs. The goal of this study was to use this interindividual variability to gain insights into the naturally occurring saccade-pursuit interactions. For that a large group of observers (N = 50) performed a series of different oculomotor paradigms to measure saccadic and pursuit behavior in isolation. To quantify saccade-pursuit interactions the combination of position and velocity errors that are necessary to trigger a corrective saccade were measured out of fixation or during steady-state pursuit. The combination of both error signals can be summarized in the eye crossing time (the time the target needs to cross the current gaze location in a step-ramp paradigm). We found that the eye crossing time leading to a minimum of corrective saccades (Center of the "Smooth Zone") varied between ~150 to 400 ms and the average was comparable during pursuit initiation and steady-state pursuit. When compared with results from the isolated experiments, saccade-pursuit interaction correlated most strongly with two measures: (1) The higher pursuit gain, the earlier the center of the "Smooth Zone", reflecting a quick ability to react to moving targets. (2) the more accurate saccades to moving targets, the later the center of the "Smooth Zone", reflecting a trigger of more early saccades to quickly catch up with the target. Therefore, saccade-pursuit interactions seem to be adapted to the strengths of the respective observer.

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Poster session 7. Surface & Texture

Optical and perceptual characterization of glossiness for hazy surfaces

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The visual perception of surface gloss is a complex multidimensional phenomenon that is influenced by different attributes. According to Hunter (1937), at least six visual attributes (specular gloss, distinctness-of-image (DOI), contrast, haze, sheen, and surface-texture-gloss) could be considered for a complete evaluation. However, these attributes are not independent and more recent studies emphasized the importance of two attributes - DOI and (brightness) contrast - in modeling the general gloss appraisal. This study aims to examine the perceived glossiness of hazy samples. To this end a set of glass samples is used with etched and polished front surfaces and black or white painted back sides, resulting in a considerable range of surface haziness at various contrast levels while

maintaining a visible DOI. Psychophysical experiments are conducted using the method of paired comparison, in a light booth with a specular light source illuminating the sample pairs. In multiple sessions, 10 observers judge different criteria for gloss and its attributes (for example 'glossiness', 'sharpness'…). Visual scales are developed for each criterium and their statistical significance is studied. A principal component analysis is executed on the resulting glossiness scale to determine the dimensionality. It is subsequently investigated to what extend the glossiness can be explained by a model which is based on a selection of attributes. In addition, the correlation between optical measurement metrics from a recently developed imaged-based gloss instrument and the obtained visual scales is evaluated as to optimize the instrument its image processing algorithms.

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The Effect of Different Quantities of Bubbles in the Glaze Layer of White Porcelain on the Impression Rating of Surface Visibility

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The surface of white porcelain is white, but there are many expressions, including translucent milky white and moist pure white. This study focused on the glaze layer, which directly affects the surface appearance of white porcelain, and examined whether different bubble quantities produce different surface impressions. The white porcelain test piece is a square 3.5 cm with two different surface shapes: convex or flat. Each test piece had either a high or low number of bubbles. Five Munsell color papers with visual matching were used as visual stimuli to compare the impression of visibility with and without a volume of bubbles. The table on which the test piece was placed was illuminated at 840 (Lux) with a color temperature of 6550 (K) or 2850 (K) from above. Observers first rated the 18 impression word pairs using the semantic differential method and then selected one color name from the 11 basic colors. Twenty-five university students participated in this experiment. The results suggest that the impressions of "clean," "beautiful," and "clear" were significantly changed by the number of bubbles. On the other hand, "moisturized," "jiggly," and "deep" showed no change for any of the stimuli. A comparison of white porcelain with a flat surface and paper of the same color suggested significantly different impressions of "shiny," "glossy," "moist," "plush," and "heavy."

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Evidence of a continuous transition between modal and amodal completions

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Perceptual completions are usually categorized as modal or amodal, depending on whether visual qualities such as brightness and color are present in the perceptually added parts or not. Therefore, visible complements like those in subjective, or illusory, figures are considered modal, whereas invisible complements of occluded parts are considered amodal. A few example stimuli in the literature might give rise to doubt that this "visibility criterion" is adequate to cover all relevant cases. However, most of these examples were only demonstrations that have not been investigated systematically under experimental conditions and have not received much attention in the community. Here I present experimental data suggesting that 1) amodal completions can also occur without occlusion (an assertion already made by Michotte), and that 2) figures can be completed partially modally and partially amodally even though they are fully unoccluded. The results challenge the prevalent assumptions that 1) amodal percepts always represent occluded parts in the proximal stimulus, and that 2) the difference between modal and amodal percepts is categorical in nature. Possible implications are discussed.

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Spatial tiling for shape segmentation

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The human visual system can differentiate textures and thus detect shapes even in the absence of clear contours or uniform filling, e.g. while viewing grainy photographs or pointillist paintings. Texture segmentation studies have classically been concerned with observers' ability to discriminate texture patches depending on pixel-to-pixel dependence, also used to measure spatial properties such as entropy. However, texture synthesis that relies on these dependencies typically leads to patterns containing highly stereotypical stimuli, such as polygons or oriented lines. The influence of more general spatial structuring on segmentation is understudied. We test this influence using aperiodic Penrose tiling of white noise patches. We systematically vary the unit tile size: the smaller the tile, the more repetition across the screen. This manipulation introduces a gradient of spatial structuring, from more entropic to more patterned. Participants report the

orientation of a target rectangle in a 4-alternative forced-choice task. We expected observers' accuracy and speed to peak when tile size is minimal, i.e., with maximal spatial structuring in both the target and background. Preliminary data support this hypothesis. We present our results when comparing these metrics under two within-subject conditions: white-noise tiling, in which the unit tile is a random arrangement of pixels, and structured tiling, with predefined structured arrangements in each unit tile.

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Cross-modal Effects of Turkish Onomatopoeic Words on Perceived Material Softness

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Perceived softness dimensions from different stimulus presentations such as names, photographs, videos of materials, or by touch yield similar dimensions: Fluidity, Deformability, Granularity, and Surface Softness. We have previously shown that Turkish onomatopoeic words and material related adjectives have unique associations (e.g., pıtır pıtır for sandy, granular; fokur fokur for fluffy), generalizing the tactile sound symbolism effect to three-dimensional everyday materials. Here we wanted to see whether this effect can aid to manipulate softness perception of everyday materials such as honey, silk, or sand. In the exploratory part, we used 47 Turkish onomatopoeic words (spoken and written) in a rating task (31 adjectives, n=43), and using a semantic differentiation method we extracted the main softness dimensions, mostly in line with the literature: Fluidity, Granularity, and Surface Softness. We did not find any factors related to deformability due to the lack of deforming sounds, hence onomatopoeic words. Next, we assessed the congruency of onomatopoeic words and videos based on their loadings on each softness dimension and ran a new rating task presenting material videos and spoken onomatopoeic words synchronously (13 adjectives x 13 materials x 2 onomatopoeic congruency x 2 rating category, n=30). For congruent word-video pairs, ratings for dimension-related adjectives were significantly higher (or lower for incongruent pairs) than for incongruent word-video pair trials where unrelated adjective ratings are not affected. We provide two lines of evidence showing the cross-modality of perceived softness dimensions: 1) by unique sound-material associations and 2) by onomatopoeic words selectively altering perceived material qualities.

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Consistent and predictable variations in gloss discrimination across viewing conditions

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Light reflected from a smooth surface can evoke the perception of gloss, yet this is not solely determined by the physical properties of the surface itself. For example, a perceived difference in gloss under one set of viewing conditions can completely disappear under another set of viewing conditions. This fundamental difficulty with predicting perceived surface gloss, whether from a physical measurement or from proximal image data, has so far hobbled efforts to establish a rigorously defined perceptual standard for gloss, similar to those that exist for color. Here, we propose an experimental framework for making this problem tractable, starting from the premise that any perceptual standard of gloss appearance must account for how distal scene variables influence the statistics of proximal image data. With this goal in mind, we rendered a large set of images in which shape, illumination, viewpoint, and surface gloss were varied. For each combination of viewing conditions, a fixed difference in surface roughness was used to create a pair of images showing the same object (from the same viewpoint and under the same lighting) with high or low gloss. Human observers (N=100) completed a paired comparisons task in which they were required to select scenes with the largest apparent gloss difference. Importantly, rankings of the scenes derived from these judgments represent how viewing conditions affect perceived gloss independent of physical reflectance. We find that these rankings are remarkably consistent across observers, and can be predicted using by a widely-used image quality metric (HDR VDP).

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How Prior Visual Information Affects Exploratory Movement Direction in Texture Perception as a Function of Information Quality and Task Difficulty

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When haptically discriminating groove-ridge gratings according to their spatial frequency, participants adapted the direction of their exploratory movement to be orthogonal to the gratings' orientation. The adaptation was based on sensory information gathered over the course of an exploration and improved discrimination performance. In

two experiments we examined if prior visual information indicating a grating orientation produces a similar adaptation of movement direction, and if task difficulty has an impact on this adaptation. In each trial, participants explored two grating textures that only differed in spatial frequency, and indicated the stimulus with the higher spatial frequency. Gratings were given in six different orientations relative to the observer. We analyzed movement directions of the first, middle and last strokes over the gratings per trial. In the initial experiment, we varied the quality of prior visual information on grating orientation in five levels: 50% (excellent information), 35%, 25%, 15% and 0% (none). In the second experiment prior visual information was given in three levels (50%, 25% and 0%) and we additionally implemented two levels of task difficulty by using stimuli with larger and smaller differences in their spatial frequencies. The results show that participants use more initial orthogonal strokes and show less variability in their movement directions when the quality of prior visual information is higher, and tend to suggest that the role of prior information is further moderated by task difficulty.

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The similarity space of fictional materials.

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Material perception research has traditionally used real objects or computer renderings for stimuli generation. In both cases, the availability of accurate control over distal characteristics aids the understanding of the fundamental relation between physical parameters and perception. Recently, researchers have also started to use paintings as stimuli. Not confined by the physics of the distal world, artists directly apply paint strokes onto the proximal canvas. This allows for a less restrictive stimulus space to probe the visual system with. The necessary visual expertise is normally restricted to artists and thus hard to reach for scientists. However, with the recent developments in DNNs, especially with generative algorithms based on text prompts, a whole new visual arsenal became available to the scientist. Here, we generated materials with Midjourney, a text-to-image service still in beta, using text prompts of the form "a [material name] sphere" where the material name came from the MERL database. The fictional stimuli exhibited many interesting peculiarities, for example the use of weird textures, unusual lighting and in general a sense of magic realism. We conducted a triplet-based ordinal embedding experiment to investigate the differences between the traditionally rendered-material space (MERL) and the text-generated-material space. While the MERL space appeared interpretable with clear clusters of reflectance (e.g. metallic, glossy and matte), the Midjourney space appeared less easy to interpret except for a small metallic cluster. The by Procrustes aligned spaces did not correlate with each other, confirming substantial categorical differences between the two.

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Poster session 8. Illusions

Body size illusions caused by polka-dot dresses

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Visual illusions can be useful in our daily lives. For example, clothing takes advantage of visual illusions to make the wearer look slimmer or better-proportioned. However, very few scientific studies have investigated such illusions except for striped clothes. We psychophysically measured visual effects of polka-dot patterns on perceived body size and height using 3D models of humans and clothes generated by computer graphics. The standard stimuli were a woman of average body shape and height wearing a dress with polka-dot patterns. The size and spacing of the polka dots varied from very small to very large. The comparison stimuli were a woman of varying size (i.e. from thin to fat and from short to tall) wearing gray full-body tights. In each trial, one of the standard stimuli and one of the comparison stimuli were presented side by side. Participants estimated their true torso shape and height and chose the stimulus that appeared fatter (Experiment 1) or that appeared taller (Experiment 2) than the other. The comparison stimulus was adjusted according to the staircase method. The experiments showed that larger dots made the person appear fatter and shorter compared with smaller dots. These results suggest that the human visual system assimilates the impression of large dots of clothing into the perception of the wearer's body shape and height.

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The existence and absence of the perceptual set effect in the task with visual illusions

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The perceptual set effect (contrast or assimilation) is well known for verbal answers for real or illusory different stimuli. We used motor tasks. The set series were the pair of the segments of real or illusory different length, the test series consist of the equal segments. The subjects drew two lines on the screen with the index finger of their right hand. Movements were carried out from left to right, from top to bottom. The perceptual set effect did not exist with the really different segments and Muller-Lyer illusion. With the Ponzo illusion, there was the assimilative effect. This result is consistent with the hypothesis of two subsystems of visual perception (actions do not require the use of memory, and therefore the perceptual set effect was not found). The effect in the Ponzo illusion could be due to the differences of Muller-Lyer and Ponzo illusions, the Ponzo illusion suggested to involve cognitive mechanisms. And that it could be the effect of the repetition error in the judgement of equal segments as different. (RSF № 22-18-00074)

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Why are mountains often higher than they look?

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According to common wisdom among hikers, mountains are often much higher than they look. One possible reason for this is that smaller protrusions in the mountainside are often mistaken for the actual peak of the mountain. To investigate the roles of amodal completion in such mistakes, we asked participants standing at the foot of a mountain to indicate their beliefs about the shape of the mountain beyond the highest visible protrusion from their point of view. This was done by completing a drawing showing the visible part ("knowledge task"). After this, the participants were also asked to draw how they immediately experienced the hidden parts of the mountain when they looked at the visible front ("perceptual task"). The completions drawn by the participants vary considerably, but the average completion was less tall than the real peak of the mountain for both tasks. Remarkably, the average slope and height of the completed mountain side for the perceptual task was significantly less than for the knowledge task. Based on these findings, we suggest that amodal volume completion may bias observers towards mistaking protrusions in a mountainside for the real peak of the mountain.

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Stimulus duration differentially effects the duration and direction of the illusory motion in the Motion Bridging Effect: Evidence for two underlying processes.

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In the "Motion Bridging Effect" a stationary ring of points appears to rotate when it follows the presentation of a rotating ring of points that spins so rapidly it is perceived as a stationary outline. The direction of the illusory rotation usually matches the direction of the preceding rotating ring, although this direction is undetectable when only the rotating 'inducing ring' is shown. The strength of this direction congruency increases as the interstimulus interval between the inducing and stationary ring is increased from 0 to about 90 ms and then declines. We now report an investigation in which, in addition to congruency, a flash benchmark and double random staircase procedure were used to measure the duration of the illusory motion as the duration of the inducing ring presentation was varied. Inducing ring durations of 30, 60, and 150 ms were employed with interstimulus intervals that ranged from 0 to 180 ms. As the interstimulus interval was increased, congruency exhibited the inverted-U shaped function found in previous studies, but was substantially reduced when the inducer duration was only 30 ms. The apparent duration of the illusory motion, however, was unaffected by the inducing ring duration and declined linearly as the interstimulus interval increased. These findings support the hypothesis that the processes that determine the congruency effect differ from those that determine the duration of the illusory rotation.

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The perceived size of visual objects defined by texture boundaries.

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In a study of whether textural contours evoke the illusion of size, psychophysical experiments were carried out with stimuli of synthetic textures of diagonal lines of fixed spatial frequency. Three versions of stimuli were formed: A, a rectangle and background, which differed from each other in the orientation of the textured lines; B, isolated texture rectangle; and C, dark or light rectangular window framed by texture, C1, and C2. Thus, rectangle A was defined by the boundaries of textural cues, while B, C1, and C2 by a combination of texture and brightness signs. For control, contoured and filled rectangles were used, D and E respectively. The subjects evaluated the perceived length of the rectangles presented on the monitor screen performing the distance matching task. The illusion of length manifested itself in all cases. It gradually grew stronger for A, B, C1 and C2 when the length of the rectangles increased like in experiments with line contours D and brightness contrast E. The average values of the curves (A), (B), (C1), and (C2) were similar to each other. The data obtained confirm the assumption that the encoding of the contours of visual objects is a main prerequisite of the common sensory phenomenon, the illusion of the size of objects. The perceived shape and size are defined by local boundaries, which in turn are determined by marks of brightness or texture

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The effect of elliptical contour and inner grating on orientation perception

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The phenomenon in which perception of an orientation is affected by perception of another orientation is called orientation illusion. In general, studies of orientation illusion investigated whether orientation illusion is observed when two orientations are existed. The purpose of this study is to investigate the effect of elliptic contour and inner grating on orientation perception using a single elliptic grating stimulus. In Experiment 1, the effect of elliptical contour on the orientation of inner grating was investigated. In Experiment 2, the effect of inner grating on the orientation of elliptical contour was examined. The results of this were followed; when the elliptical contour was close to vertical, the orientation of inner grating was perceived close to vertical. When the elliptical contour was close to horizontal, the orientation of the inner grating was perceived as close to horizontal. When both the orientation of the elliptical contour and inner grating was 45 degrees, the orientation of the inner grating and elliptical contour were perceived as close to vertical. These results showed that orientation perception is mainly affected by external orientation within a single stimulus, suggesting that external orientation is more affected by perception rather than absolute orientation. The results suggest that the orientation illusion of elliptic grating stimulus may be different from other orientation illusions.

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The Effect of the shape of a frame on rod-frame illusion

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The rod-and-frame illusion (RFI) is perceived by the virtual axis inside the frame, where as the tilt illusion (TI) is perceived by the orientation difference between the central and surrounding stimuli. Many studies mainly used the square frame as stimulus, hence failed to investigate whether the RFI was induced by the orientation of individual line or entire frame, since the orientation of the rod could induce either TI or RFI. In Experiment 1, the effect of the frame ratio on the RFI was investigated using a rectangular and a square frame. In Experiment 2, to investigate the effect of the distance between the rectangular frame and the rod on the RFI, the gap of the short line of the rectangular frame was manipulated. The results showed that the RFI was induced when a square frame was presented. When a frame with a low ratio was presented, repulsion was occurred. When a frame with a high ratio was presented, attraction was occurred. When the gap between the rod and the frame was controlled, both repulsion and attraction were occurred. These results showed that the orientation of the frame affects the perception of orientation of rod, as well as the orientation of the individual lines, suggesting that the RFI also included not only earlier orientation processing but later shape processing.

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The Effect of Line segment's connectivity on Neon color and texture spreading

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In a figure consisting of black lines, changing the color of some segments to a chromatic color induces the neon color spreading where the neon-like glow of the color is perceived as if the color spread out to the background between the colored segment. In this phenomenon, the illusion weakens when the black and colored segments are not connected. Many studies identified the influence of the connectivity at the boundary between the segments, but no within the segments. The current study explored the effect of the line segment's connectivity

by composing figures with dotted lines where the lines are broken with regular gaps. In these stimuli, the texture spreading could also occur with color spreading. By comparing the intensity of diffused texture in stimuli where the whole figure was comprised of the dotted lines and that in figures where only colored segments were dotted lines, the contextual effect on the neon color spreading was investigated. The results showed that neon color spreading occurred even in figures composed of dotted lines, and that texture spreading appeared stronger when only colored segments were dotted lines than when entire lines were dotted lines. These results suggest that neon color spreading can be influenced by top-down processing as well as the early stages of visual processing.

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Does induced depth contribute to the Dynamic Ebbinghaus illusion?

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In the Ebbinghaus illusion, a test disk surrounded by smaller disks appears larger than one surrounded by larger disks. Recently, Mruczek et al. (2015) reported a dramatic increase for this illusion in a dynamic version where the stimulus moved as the surround disks changed size from small to large while the test in the center always had the same size. Here we examined whether the increased illusion was due to a perceived depth change induced by the dynamic stimulus. Specifically, the dynamic size change of the surrounds can produce a looming effect that would make the test in the largest surrounds appear closer and therefore even smaller while the test in the smaller surrounds would appear farther and so larger. The experiment attempted to cancel the induced depth change on the test by grouping it with a remote background of dots that moved with the stimulus but remained the same size. In this case, the dynamic surround disks continued to loom and recede, but the test disk avoided any depth change this would have induced. The remote dot field reduced the illusion to the same magnitude as the standard illusion whereas the remote dots did not reduce the standard illusion itself. The results suggest that the pictorial depth effect due the size change in the Dynamic Ebbinghaus Illusion may be one of the factors that increases the illusion size in the dynamic case.

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Exploring changes in temporal contrast and perceived size.

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Visual illusions that affect the perceived size of an object, such as the Ebbinghaus and Delboeuf illusions, often make use of a comparison or reference disc to be able to determine the illusory effect on perceived size. In these experiments, it is also custom to include a control condition, in which participants are asked to judge the size of the comparison disc presented on a neutral grey background, relative to a disc of fixed size presented on the same neutral background. This control condition, however, is rarely investigated in detail. Therefore, in a series of simple experiments, we investigated how the contrast between a disc and the background on which it presented affect the discs' perceived size. Participants are shown a disc on a background of a given intensity after which a second disc is presented on a background of a different intensity. Participants are then asked to identify the larger of the two discs. By varying the size of one of the two discs on a trial-by-trial basis, we located the point of subjective equality to determine if the contrast between disc and background influences the perceived size of the disc. This allows us to identify the possible contribution of figure-ground contrast to perceived size.

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Towards an understanding of the Shepard tabletop illusion

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The Shepard tabletop illusion is one of the most powerful geometrical illusions in which two identical parallelograms presented as tabletops are perceived as different in aspect ratio when depicted at different angles. Specifically, the vertical parallelogram appears as a long and thin rectangle, whereas the horizontal parallelogram appears approximately as a square. The illusion is typically explained by theories of depth perception: the vertical parallelogram is treated as a 3D object that recedes into the distance while the horizontal parallelogram as an object closer in view. Here, we examined the role of depth cues, texture, shape constancy, and mental rotation abilities in the illusion.

We quantified illusion magnitude in 66 participants (53 females) using the method of adjustment. By manipulating depth cues and texture, we created four conditions: i) plain parallelograms; ii) plain tables (parallelograms with legs); iii) wood-like parallelograms; iv) wood-like tables. Also, participants completed a shape constancy task by adjusting the shape of a square on a computer screen to match the same square viewed at different slant angles. Finally, mental rotation abilities were measured using a classic matching task. We found that the illusion increased with the incorporation of additional depth cues, whereas adding the wood-grain texture specifically to the table configuration diminished its strength. Interestingly, the illusion correlated with mental rotation and not with shape constancy abilities. Taken together, these findings demonstrate that the illusion cannot be explained solely by depth perception. Indeed, mental rotation abilities and low-level visual features (texture) seem to contribute as well.

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Illusory contours evoke, and filling elements reinforce the expansion of the perceived size

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In psychophysical experiments with illusory Kanizsa-type rectangles, observers perceived the distance between nonexistent boundaries as longer than determined by the stimulus drawings. The elongation value gradually grew when the length of rectangles increased similar to experiments with real contoured and filled rectangles. In experiments with the Oppel-Kundt stimulus, according to the classics, the perceived length of the filled interval first increased from zero to maximum and then slightly decreased with the number of stripes (0 – 30). If the filling stripes were removed from the stimulus, but their end points remained, the perceptual errors did not disappear, only the experimental curve decreased somewhat, and the maximum smoothed. If two horizontal lines were added to the filled Oppel-Kundt stimulus interval, forming a contour rectangle, the perceptual errors were also present but remained approximately stable with various numbers of the filling stripes, and the curve approached the horizontal line. The data obtained showed that illusory contours could be as effective as real edges in the genesis of size expansion. The sense of illusory outline arose and intensified with increasing number of points in the line. The results confirmed the assumption that the Oppel-Kundt effect is an individual case of a general sensory phenomenon: the illusion of the size of visual objects. The decisive feature of the Oppel-Kundt object is horizontal illusory contours. The filling stripes themselves are auxiliary functional factors that, indicating the properties of the stimulus surface, emphasize its edges.

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The effect of thickness and contrast of the induced line on orientation perception of subjective contour in the Zöllner illusion

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Orientation perception of the Zöllner and the tilt illusion is determined by the surrounding or inducing stimuli. In general, the tilt illusion is determined by the physical similarity between the inducing stimuli and the induced stimuli. In this study, the effect of physical similarity on the Zöllner illusion was investigated. The inducing lines were real, and the induced lines were subjective or real contours. The thickness of lines, the luminance contrast of the inducing-induced lines, and the phase difference of the inducing lines were examined. The strong Zöllner illusion was observed in the subjective contour condition as well as the real contour condition. In the subjective contour condition, the illusion was decreased as inducing lines were getting thicker, regardless of the thickness of the induced lines. The illusion was reduced when the luminance contrast of lines was high in the real contour. The phase difference of the inducing lines did not affect the illusion. These results show that the perceptual clarity of the induced lines rather than the physical similarity of lines affects the Zöllner illusion suggesting the mechanisms of the Zöllner illusion and the tilt illusion are different.

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The effect of motion direction of surrounding stimuli and ratio of moving dots on the tilt illusion

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When objects are fast-moving in a specific direction, motion streaks are generated. Motion streaks are processed in the earlier stages of visual processing. Motion streaks are known to induce the tilt illusion (TI), which is considered a strong evidence for interactions between motion and form pathways. This study investigated whether the TI is affected by motion streaks and canceled by the opposite bidirectional motion. In Experiment 1, the effect of unidirectional motion direction and ratio of moving dots in surrounding stimuli on TI was investigated. In Experiment 2, the effect of bidirectional motion from

opposite directions and ratio of moving dots in surrounding stimuli on the TI was examined. In Experiment 3, whether the TI could be induced when two motions with different direction were perceived as one vector-average direction. The results showed that motion direction did not affect on TI. TI was observed more clearly when the ratio of moving dots was increased. TI was also observed when ratios of unidirectional and bidirectional moving dots were the same. But TI was disappeared when the motion direction was perceived as the vector-average. These results show that TI was induced by the absolute amount of motion streaks. When the ratio of bidirectional moving dots was higher than half, the TI was decreased. These results suggest that the effect of motion streaks on form information may be processed not only in the earlier stages of visual information processing but also in the later stages.

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Effect of implied motion in pictograms on perceived presentation duration

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The presentation duration of a moving object is often perceived to be longer than that of a static object when the objects' durations are physically equal to each other. Previous research revealed that, when physically equal, the presentation duration of a running man represented by a realistic stationary figure is also perceived as being longer than that of a standing man. In this research, we investigated whether perceived presentation duration is also affected for pictograms made of simple components by the implied speed in the pictograms' figures. We created a pictogram representing a running man, and varied the angle of tilt from 0 to 24 degrees in steps of 8 degrees. The pictograms with the four tilt angles were individually presented below a fixation cross, with a presentation duration of 300, 600 or 900 ms. Participants were asked to evaluate the motion speed implied in the stimulus by providing a number. They were also asked to reproduce the presentation duration by pressing a key, making the key press duration subjectively equal to the duration of the presented stimulus. The evaluations confirmed that the implied speed increased with the angle of the pictogram, that is, the running man's implied speed became higher when the tilt angle became more extreme. The results of the reproduction task showed that the perceived duration also increased with the angle of the pictogram. These results indicate that perceived presentation duration can be modified by implied motion speed even in simplified, symbolic figures.

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Poster session
9. Multisensory Perception

Auditory pitch modulation of binocular rivalry

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When the two dissimilar images are presented to the two eyes, observers typically perceive one of the images. This phenomenon, which called binocular rivalry, has been studied by several approaches including the influence of cross-modal interaction. In the researches of audiovisual interactions, auditory pitch has been revealed to have correspondences with various dimensions of vision.

The present study investigated the influence of the change in auditory pitch on binocular motion perception. The sounds that ascending or descending in pitch were presented with the dichoptically-presented random-dot kinematograms (RDKs) which contains the vertical motion. Duration of the periods which either of the rising or falling dot motion was dominantly perceived was recorded and compared with the congruent (e.g., rising in sound and motion) and incongruent (e.g., rising in sound and falling in motion) combinations.

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Summation of auditory and visual speech in upright and inverted faces

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Seeing the face (mouth) of a talker can greatly facilitate recognition of speech sounds. However, it is not well understood how specific this summation is to various properties of visual stimuli. It is known that face perception is sensitive to global orientation so that upright faces are much easier to process in perceptual tasks than inverted. Here, we used psychophysical subthreshold summation paradigm to quantify how strongly auditory and visual information is summed (integrated) in audio-visual speech perception and asked whether summation in is sensitive to orientation of face, i.e. whether strong audio-visual speech summation is only possible with upright, "typical" faces.

Discrimination thresholds for auditory, visual and audiovisual spoken syllables [ka] and [pa] presented in white noise were measured for both upright and inverted faces cropped so that only mouths were visible. Then, we fitted a Minkowski metric that compares the thresholds in audiovisual conditions and allows to quantify the strength of audio-visual summation.

We found strong perceptual summation for auditory and visual information in speech recognition. Further, even when face inversion led to approximately 55% increase in visual thresholds it did not change the strength of audiovisual summation, which was as strong both for the upright and inverted faces (Minkowski exponent k 1.4 vs 1.3, respectively). Such low k values mean that it was possible to discriminate audio-visual stimuli even when the components were much below their individual discrimination thresholds. Thus, even when face inversion dramatically hindered visual speech recognition, summation of audiovisual speech signals was not affected.

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Effects of perceptual regularity and crossmodal audiovisual congruency in perceived fit and pleasantness

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We studied crossmodal aesthetic effects of simple visual patterns and auditory tones. The visual patterns comprised pairs of shapes (e.g. rectangles, ovals). In each pair, the shapes were positioned next to each other and had either an oblique orientation or a horizontal orientation, such that the global outline of the pair of shapes revealed either symmetry, repetition or neither. The simultaneously presented tones had a variable pitch (rising, falling, or continuous) and were such that the auditory pattern was either congruent, partially congruent or incongruent with the visual pattern. For example, in case of a visual symmetry, both shapes could be positioned with an oblique orientation forming an overall symmetry pointing upwards, and could then be combined with a rising pitch followed by a falling pitch (congruent), or with a falling pitch followed by a rising pitch (partially congruent), or with a continuous pitch and a rising pitch (incongruent). In the experiment, participants were asked to rate the fit and, in a different block, the pleasantness between the visual pattern and the tones (using a 7 point Likert scale). The effect of congruency on both fit and pleasantness turned out to be significant. More specifically, a partially different pattern of results was found when, with the same stimuli, participants were asked about the fit between the visual and auditory stimuli as compared to when they were asked about the pleasantness of the stimuli. We will discuss the results in relation to other crossmodal findings known in the literature.

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Combining Visual and Haptic Cues in Weight Perception

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Combining different cues to an environmental property can improve perceptual estimates, e.g. judgments of an object's size via both visual and haptic cues can produce more precise estimates than with either cue individually. Here, we investigated whether cue combination also leads to more precise weight perception. We hypothesise that the availability of visual and haptic cues will enhance weight estimation, compared to the best single cue.

19 participants judged which of two jars was heavier. The jars contained different amounts of sand and were presented in three cue conditions: visual, haptic, or visuo-haptic. In the visual cue condition, participants viewed the contents of transparent jars; in the haptic cue condition, they lifted opaque jars; in the visuo-haptic cue condition, they lifted transparent jars.

Reliabilities of the two single cues were well matched (mean sigma = 16.7 grams visual; 17.1 grams haptic). 9 of 19 participants made more precise judgments in the visuo-haptic (mean sigma = 12.7 grams) than their best single-cue condition, no more than expected by chance.

The availability of simultaneous visual and haptic cues did not improve performance in weight perception compared to the best single cue. Possibly, people do not efficiently combine these two information sources, but a larger participant sample is needed to draw firm conclusions. This initial data will inform a power analysis to determine the sample size needed to detect a combination effect.

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Auditory Localization Performance can be Enhanced by both Visual and Audiovisual Short-term Training

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Localizing the sound source is a difficult task that one can practice while learning to play a musical instrument or living in outdoor environments. Studies on multisensory effects in sound localization suggest that integrating stimuli from different senses may enhance localization performance. We investigate the role of visual and auditory integration on sound localization by focusing on unimodal and multimodal training and presentation types.

In the first experiment, we examined the effect of training type with 54 participants. Participants went through two types of training sessions: listening to object originating sounds in repetitive or sequential patterns. The type of training sessions did not affect the sound localization performance, indicating that short-term training fails to retain any auditory learning effect.

In the second experiment, we investigated the effect of training modality on sound localization performance. 25 participants were tested in each of the four training conditions (auditory, visual, audiovisual, no-prime). Performance for the audiovisual condition was higher in auditory and no-prime conditions, while audiovisual and visual conditions did not show a significant difference in localization performance. These results show that (1)when participants receive information from two different sensory modalities, their performance significantly improves compared to auditory conditions and (2)visual information can be as useful as auditory information. The latter could be due to sensory recall of prior experiences with similar objects. Our results comply with the visual-dominance hypothesis that emphasizes superior spatial acuity of vision. [Research was supported by the grant no.121k715 from Scientific and Technological Research Council of Turkey (TÜBİTAK)]

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Characterizing auditory and visual motion processing and integration in hMT+/V5 and Planum Temporale with ultra-high-field fMRI (7T).

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The ability of the brain to integrate motion information originating from separate sensory modalities is fundamental to efficiently interact with our dynamic environment. The human occipito-temporal visual region hMT+/V5 and the auditory area Planum Temporale (PT) are known to be highly specialized to process visual and auditory motion directions, respectively. In addition to their role in processing the dominant sensory information, it was recently suggested that these regions may also engage in crossmodal motion processing. How multisensory information is represented in these regions remain however poorly understood. To further investigate the multisensory nature of hMT+/V5 and PT, we characterized single-subject activity with ultra-high field (UHF) fMRI (7T) when participants processed horizontal and vertical motion stimuli delivered through vision, audition, or a combination of both modalities simultaneously. Our preliminary results confirmed that in addition to a robust selectivity for visual motion, portion of hMT+/V5 selectively responds to moving sounds and a portion of PT responds to moving visual stimuli. We are now further characterizing the brain activity in the cortical depths using UHF fMRI combined with vascular space occupancy (VASO) recording at high spatial resolution (.75mm isotropic). We hypothesize that hMT+/V5 and PT might encode auditory and visual motion information in separate cortical layers, reflecting the feed-forward versus feedback nature of how sensory information flows into those regions. This project will shed new lights on how crossmodal information is represented across the depth of the cortical layers of motion selective human brain areas.

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Visual and vestibular stimulation interact in time perception

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Visual and vestibular can be at odds during complex behaviors or when watching movies. Numerous studies reported effects of vestibular and visual information on time perception, but little is known about their interaction in temporal processing.

To investigate this, we conducted three experiments in which subjects produced time intervals with their eyes closed or open while being exposed to different levels of additional vestibular challenge. In Experiment 1, participants produced intervals of 5 to 20 seconds while standing on both feet. In Experiment 2, participants performed temporal productions of 10- or 15-second intervals while standing on both feet or actively balancing on one foot. In Experiment 3, participants were lying in a nest swing and produced durations of 5 to 20 seconds with or without additional passive vestibular stimulation induced by the oscillatory movements of the swing.

Without additional vestibular challenge, i.e. standing on both feet or lying in the swing at rest, we found longer temporal productions with eyes closed. In contrast, in the conditions with additional active or passive vestibular stimulation, i.e. balancing on one foot or lying in the swing in motion, the effect of eye closure vanished. The effect of additional vestibular challenge on time perception was task-dependent. Whereas the produced time intervals remained largely unaffected during balancing on one foot, we found that the passive vestibular stimulation through the swing in motion led to temporal overproductions. Our results point to a situation-specific interaction of visual and vestibular cues in time perception.

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Modulation of perception by visual, auditory and audiovisual reward predicting cues

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It is unclear whether reward-driven modulation of perception follows the same principles when reward is cued through a single or multiple sensory modalities. We previously showed that task-irrelevant reward cues modulate perception both intra- as well as cross-modally, likely through a putative enhancement in the integration of stimulus parts into a coherent object. In this study, we explicitly test this possibility by assessing whether reward enhances the supra-additive integration of unisensory components of a multisensory object.

Towards this aim, we designed a simple detection task using reward predicting cues that were either unisensory (auditory or visual, both above the detection threshold) or multisensory (audiovisual). We expected that reward speeds up reaction times in response to all stimulus configurations, and additionally reward effects in multisensory cues fulfill the supra-additive principle of multisensory integration. We observed that reward decreased response times, however this behavioral effect did not reach the supra-additive threshold. Neuroimaging results demonstrated strong supra-additive responses to audiovisual stimuli in areas such as the Superior Temporal Sulcus (STS) that are known to be involved in audiovisual integration. However, reward did not enhance the supra-additivity in STS compared to a no reward condition. Instead, inferior temporal areas with a weaker supra-additivity of auditory and visual responses were significantly modulated by reward. Overall, our results indicate that reward does not enhance multisensory integration through a supra-additive rule but is added as a constant gain factor to integrated audiovisual responses.

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Behavioural relevance of haptic processing of object size in the primary visual cortex

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Human neuroimaging work shows that the primary visual cortex (V1) in sighted individuals is recruited during haptic exploration of objects. Is haptic processing of object size in V1 relevant for behaviour? We tested eight individuals and examined whether V1 has a role in size estimation of haptically explored objects.

At each trial, an auditory cue instructed participants to haptically explore one of three unseen differently sized objects (small, medium, and large) until they heard another auditory cue 4 s later, which instructed them to return the hand to the home position. During the haptic exploration of the object participants fixated a central cross on a monitor and used the right-dominant hand to explore the object placed behind the monitor. In the experimental trials (Noise conditions), a patch of dynamic visual noise was presented in central vision to disrupt haptic processing in V1, if present. In the control trials no noise was presented (No noise condition). After the haptic exploration of the object, participants were asked to manually estimate the size of the object that they haptically explored by opening the thumb and index finger. The estimated object size was measured by using a digital caliper.

Results show that size estimation is less accurate in the Noise as compared to No noise condition, suggesting that the foveal cortex has a causal role in haptic exploration of object size. Follow-up experiments will investigate the role of visual attention and the temporal dynamics of tactile processing in V1.

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30 August 2022

Symposium 4. Cortical Circuitry Mapping using Connective Field Modelling (CFM) in perception and ophthalmic and neurologic disease

Extrastriate visual cortex contains multiple somatosensory homunculi

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Our experiences of the world are integrated, multisensory, and embodied wholes. But how the brain integrates the information originating from its different sensory maps

remains enigmatic. We have recently shown that BOLD fluctuations throughout the brain can be explained as a function of the activation pattern on V1's topographic map. This approach to functional connectivity allows us to project V1's map of visual space into the rest of the brain and discover previously unknown visual organization. Here, we extend this principle to somatosensory topography by fitting multi-modal connective field models originating from V1 and S1 simultaneously, explaining responses throughout the brain. Surprisingly, we discover multiple full somatosensory homunculi in high-level visual cortex, during purely visual stimulation. These homunculi overlap with the extra-striate body area (EBA, colocalized with the motion-selective human MT complex) and fusiform body area (FBA). Here we show these regions to have substantial, structured somatotopic tuning – in addition to their known visual tuning to images of bodies and retinotopic location. These results highlight the intimate integration of the different senses in the brain that likely gives rise to the richness of our embodied visual experience of the world.

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Convergence along the visual hierarchy for explaining Complex Visual Dysfunctions: the Posterior Cortical Atrophy Model

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Posterior cortical atrophy (PCA) is a rare visual variant of Alzheimer-disease. We recently suggested that abnormal population receptive fields (pRFs) properties are associated with PCA's classical symptoms. Specifically, simultanagnosia, the inability to perceive multiple items simultaneously, can be explained by smaller peripheral pRFs, and foveal crowding, in which nearby distractors interfere with object perception, may result from larger foveal pRFs. These effects occurred predominantly in V1, even though atrophy mainly involves high-order areas. In the current study, we used connective field modeling to better understand these inter-area interactions.

We used fMRI to scan six PCA patients and eight controls while they viewed drifting bar stimuli. Resting-state data were also collected. Connective field modeling was applied for both conditions: once when the source was V1 and the targets were extrastriate areas and once for the opposite direction. The difference between the two was defined as convergence magnitude.

With stimulus, the convergence magnitude of the controls increased along the visual pathway, suggesting that spatial integration from V1 becomes larger up the visual hierarchy. No such slope was found in the PCA patients. The difference between the groups originated mainly from the dorsal pathway. Without stimulus, the convergence magnitude was negative, slightly more so for the PCA patients, with no slope, suggesting constant divergence along the visual hierarchy.

Atrophy in one part of the visual system can affect other areas within the network through complex intervisual area interactions, resulting in modulation of population receptive field properties and an ensemble of visuocognitive function impairments.

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Primary open angle glaucoma is associated with connective field changes in early visual cortex

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Glaucoma is a neurodegenerative ophthalmic disease, characterized by ganglion cell loss and loss of visual field (VF) sensitivity that is detected in the periphery. Brain imaging studies have shown the degenerative damage is not limited to the eye and optic nerve but extends intracranially along the visual pathways and into the visual cortex. However, the extent to which this affects the functioning of the adult visual cortex is not yet fully understood. Here, we used CF modeling to examine differences between early visual cortical areas in glaucoma and healthy participants using both resting state (RS) and stimulus-driven fMRI data. As a second experiment, for each participant with glaucoma, a matched control participant observed the visual stimuli with a simulated scotoma (SS) that was designed to mimic the former's visual sensitivity as assessed using standard automated perimetry. By comparing results from these groups and experiments, we can establish how differences in CF parameters, in particular CF size, are related to the ocular damage altering the visual input to the cortex. Our results show that in both RS and stimulus-driven conditions, the CFs in early visual areas V2 and V3 are smaller in glaucoma compared to control participants. This reduction in CF size was absent in the control group with SS. Neither was CF size correlated with the severity of glaucoma. We conclude the observed differences in CF may be the result of neurodegeneration or local reorganization of the early visual cortex that appears to have developed at an early disease stage.

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Next-generation Connective Field Modeling

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A promising way to model functional connectivity is to explain brain responses as a spatially structured sampling of responses elsewhere in the brain: connective field (CF) models. Typical linear CF models predict responses by combining a two-dimensional Gaussian field on the V1 cortical surface with V1's ongoing activity pattern. However, linear CFs, defined in terms of distance on the cortical manifold, suffer from several limitations. First, since the two hemispheres represent distinct cortical surfaces CF models can sample only from one single hemisphere. This separates V1 responses that correspond to neighboring positions on opposite sides of the vertical meridian of the visual field - belying the phenomenological continuity of visual space. Second, linear CF models disregard the fact that cortical computations are inherently nonlinear. Our work addresses these limitations in two ways. First, we re-define connective field models over distance in visual space, as defined by independent population receptive field (pRF) estimation. Secondly, we extend the Gaussian connective field model to incorporate divisive normalization (DN), a nonlinear computation that captures both suppressive and compressive response properties. We first demonstrate that visual space-defined connective fields outperform cortical distance-defined connective fields for many portions of the visual system, but most notably not for foveal portions, likely due to cortical magnification. Secondly, we demonstrate that DN CF models outperform linear ones throughout the visual system. Together, these results suggest that connective fields operate at the level of visual space and that divisive normalization may better capture the computation chain of the visual hierarchy.

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Connectopic mapping and spatial statistical analysis for understanding individual differences in topographic brain organisation.

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Visual brain areas are topographically organised: they exhibit point-wise mappings such that nearby locations in one region connect to nearby locations in another region. These connection topographies ensure the preservation of retinotopic organisation along the visual processing pathways and are thought to be essential for visual perception.

An important open question is how and depending on what factors this organisation varies across individuals. Methods that allow for estimating connectopic organisation based on resting-state fMRI data provide an opportunity to answering this question using existing datasets of thousands of individuals. They also deal elegantly with the problems associated with mapping retinotopic organisation in individuals who cannot be visually stimulated or individuals with unstable fixation.

While methods such as Connective Field Modelling can be applied to resting-state fMRI data, the ensuing voxel-wise estimates can be rather noisy at the individual level, require assumptions about the organisation of the seed-area, and do not lend themselves well for statistical inference over maps. We therefore developed Connectopic Mapping: a fully data-driven, multivariate alternative that also incorporates spatial statistical modelling to summarise the estimated maps in a small set of coefficients that can be submitted to standard statistical procedures such as linear regression.

In this talk I will first present the Connectopic Mapping framework, its strengths and limitations, as well as example applications. I will then close off by summarising the presented work of this symposium and discuss which enhancements to circuitry mapping will further improve our ability to link visual cortical anatomy, function, and dynamics.

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Symposium 5. Perception and (inter)actions in the real world and XR: Virtually the same or really different?

Using virtual and real environments to study tool use: virtually identical, or really different?

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For sensorimotor control researchers, VR seems to promise an ideal union of real-world complexity with (high) levels of stimulus control afforded by traditional lab-based methods. Our research aims to understand how properties of handheld tools are taken into account in sensorimotor control. Here, VR's potential to independently manipulate contributory sensory signals, and vary tool properties parametrically in software, could provide powerful means to

evaluate quantitative hypotheses. Unfortunately, however, VR often introduces uncontrolled (i.e. incorrect) sensory signals, with confounding effects. In principle, VR that reproduces all sensory signals with sufficient fidelity could pass a sensorimotor Turing test: the sensorimotor system could not 'discriminate' it from an equivalent real scene. Work on 3d visual displays highlights how difficult this is to achieve in practice, however, and even seemingly unimportant sensory signals can, when incorrect, result in significant differences to real-world perception. This is consistent with models of sensory integration that suggest the brain uses all available signals, and that the contribution of each signal depends on context, making it difficult to predict when incorrect information will matter. These issues seem acute in tool-use studies, given the inherent difficulty of realistically simulating haptic signals, and properties of tools (e.g. inertia, vibratory tactile information). Our studies in fully real, mixed (virtual visual/real haptic) and fully virtual environments, suggest significant discrepancies can emerge regarding key findings. Thus, while VR has notable virtues, we argue for healthy scepticism when generalising findings from tool-use studies in VR to natural behaviour, and advocate triangulation with real-world settings.

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Proximity in virtual reality: Using social behaviour to study perception of virtual characters

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Studies in virtual reality which focused on the perception of agents and avatars frequently reported findings comparable to real-world social interactions. To characterize how people interact with others in the same environment, proximity or personal space can be used as a measure. Users in virtual reality keep similar distances between themselves and other avatars (other users embodied in virtual characters) or agents (pre-recorded and animated characters or algorithm-driven characters) in virtual reality space as they do in physical reality. However, certain determinants of proximity exist which need to be satisfied in order for the proximity to be used as an ecologically valid way to study social behaviour of humans. These include: the scale of virtual environment matching the physical reality scale, social presence with the virtual character, presence of the self-avatar, etc. On the other hand, the failure to meet some determinants can be an indicator of the level of immersion or social presence with the virtual characters. In this way, proximity can be used to evaluate the design of virtual humans – the characters are believable if the proximity patterns in virtual reality are similar to the ones measured in physical reality. Both aspects of the proximity measure, whether it is used to explore human social behaviour or as an indicator of character design in virtual reality, have drawbacks. In this presentation, we will discuss the advantages, drawbacks and the considerations of the proximity measure in virtual reality to characterize social behaviour and evaluate virtual humans design.

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Sensorimotor prediction in virtual object interaction

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Prediction plays a central role in both perception and action. It is needed to overcome sensory processing delays and to differentiate external from self-produced sensory events. This latter ability has been explained by forward models which exploit efference copy signals to generate predictions about the sensory action effects. These predicted sensory consequences are compared with the actual sensory feedback of the movement leading to a downregulation of the sensory input if both signals match, a phenomenon termed tactile suppression. Based on highly controlled psychophysical experiments it has been shown that tactile suppression is dynamically tuned over the course of a movement, depends on the current feedback processing demands and stems from precise sensory predictions. These experiments revealed very valuable results, but were often restricted to small-scale movements and rather impoverished laboratory settings. Virtual reality (VR) enables us to study predictive mechanisms in more complex, dynamically changing 3D environments ranging from small-scale to large-scale movements, still under high experimental control. In my talk, I will present two studies evaluating the suitability of out-of-the-box VR equipment to measure tactile detection thresholds and eye movements in virtual 3D scenes. I will then present some recent VR experiments on sensorimotor prediction and tactile suppression in dynamic object interaction. Overall, our findings show that the available VR equipment can be used for psychophysical testing and opens up novel avenues to examine the limits of sensorimotor prediction by creating increasingly complex and dynamic environments that can easily violate the laws of physics.

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Visual perception and grasping of virtual and augmented objects in mixed reality

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Grasping and picking up objects are tasks that we perform in our everyday life without too much effort and appreciable errors. The visual appearance of objects seems to play an important role in the first steps of grasping movements. Besides the common real world-experience, Virtual Reality systems are spread in many different contexts. Various forms of interaction are adopted to allow the users to act inside the virtual environments (VEs) and manipulate objects. Solutions allowing natural, e.g., bare hands, interaction are still less robust than standard, e.g., controlled-based, ones. Many factors affect the grasping actions of virtual objects: errors and inconsistencies in the tracking of the users' fingers, thus in their replica inside the VE, the lack of tactile and haptic feedback, the absence of friction and weight. Mixed Reality (MR), i.e., the combination of VR and real-world elements, appears in this context challenging and promising. The main challenge is to maintain the alignment between the virtual and real reference frames, to keep the perceptual (visual) coherence of the MR environment. Then, in MR, it is possible to modify the visual aspect of real objects by preserving their physical properties but modulating and augmenting their visual aspect. Both natural and supernatural situations can be simulated, allowing the creation of novel interactive systems and the study of the interplay between visual perception and grasping actions.

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Symposium 6. ToddFest: Perception of 3D Shape, Space, and Materials Celebrating 43 Years of Jim Todd

Geometry, Jim Todd, and me

Jan Koenderink[1]
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Throughout many years I collaborated with Jim Todd on various aspects of visual space and form.

The topic of the "geometry" of the mind as it was revealed in operationalisations of visual awareness came up over and over again.

I'll just pick out one topic, that of "pictorial space."

Pictures are different from views out of windows, for pictorial space is a constrained hallucination, not the view of some physical scene.

We discovered by accident that the commonly encountered idiosyncracies are not arbitrary, but comprise a tight group of transformations.

In retrospect these are "explained" as the group of ambiguities of the "pictorial cues."

We should really have predicted what we discovered serendipitously.

This group of transformations is a key to pictorial space.

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Shape - space - material - light interactions

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Shape, materials, and the light field interact optically and perceptually. The resulting ambiguities can be highly constrained and thus, although judgments are often systematically distorted relative to the actual structure of an observed scene, these distortions are typically constrained to a limited class of transformations (Todd, Cognitive Sciences, 2004). Current thinking in terms of weighted configurations of properties (Todd & Petrov, JOV 2022) and information utility provide handles on information robustness.

One of the current challenges is to find out which configurations of which properties we need to describe an ecologically valid, wide range of natural scenes. In a variety of experimental paradigms, we used weighted mixtures of canonical modes of materials and light fields, as representatives of key properties of appearance. We found many systematic interactions agreeing with the ideas above, and, moreover, found that such interactions are predictable, providing opportunities for practical applications. Interestingly, our studies also shed light on differences in robustness of shape, material and light perceptions for the limited range of test conditions. Findings suggest that the key properties might be more robust across different materials than across different lightings and, thus, more diagnostic for materials than for lightings, causing asymmetric perceptual confounds. This may be related to information utility in an ecological perspective and how we can trust our eyes (but not believe them).

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Aging and the perception of shape, material, and environmental distance

J. Farley Norman[1]
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In my work with James Todd over the past 32 years, we have together investigated many important aspects of

visual perception. It is necessarily true that all of us are subject to the effects of aging, and aging is accompanied by neurophysiological changes in brain function. Thus, aging produces changes in our perceptual capabilities as we grow older. In this talk, I will describe my efforts to extend Jim's many and varied research interests (solid object shape, surface material, environmental distance) to include the effects of aging. The outcome of this research program has been interesting and perhaps unexpected. While some aspects of visual and haptic perception do deteriorate as one becomes older, it is also true that other important abilities remain constant and effective until at least the age of 85 years. It is even perhaps more surprising to find that other important perceptual abilities appear to improve with increasing age, so that the performance of older adults in their 70's and 80's is superior to that of younger adults.

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Visual information about 3D shape from luminance curvature

James Todd[1]
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In a classic paper on the computation of 3D shape from shading, Koenderink and van Doorn (1980) pointed out that images and surfaces have the same basic mathematical structure, and that they both can be analyzed using differential geometry. In this talk I will summarize some recent theoretical and empirical findings that have expanded upon their original insight. These new findings have shown that the second order differential structure of images provides useful information to identify surface concavities from patterns of image shading, and that similar information can be used to define the perceptual boundaries of bumps on a surface.

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Symposium 7. Multistable perception: when and how bottom-up and top-down interact?

Spread the word: Perceptual switches propagate new state within spatial surround

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A perceptual switch in multistable displays is associated with sweeping changes throughout a hierarchy of visual areas. But do these changes influence only the object itself or do they also affect the surround? One way to assess this is by using several identical or similar multistable displays and examining how the fate of a specific object influences the rest. Typically, all objects tend to synchronize their perceptually dominant states and switch in accord (a.k.a. perceptual coupling). This synchronization was attributed to the influence of a perceptually dominant state that spreads into surround via either top-down stabilizing feedback or local lateral connections. However, a closer look at the original results reveals that they are incompatible with the idea of state-induced bias. Instead, they are better explained by a tentative change-induced transient influence. We demonstrated this transient effect experimentally by combining an asynchronous presentation of bistable kinetic-depth effect displays and precisely timed exogenously triggered perceptual switches. We used a hierarchical non-linear Bayesian model to quantify this transient bias, estimating that it was induced 50–70 ms after the exogenous trigger event and decayed within ~200–300 ms. The observed bias is compatible with both a transient selective visual attention framework and local lateral connections within sensory representations. Interestingly, the transient influence was associated with a change in perception irrespective of the stimulus ambiguity. This indicates that any perceptual change, whether endogenous or exogenous, activates similar mechanisms of perceptual reevaluation within a spatial surround, facilitating perceptual inference for dynamic visual scene perception.

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Computational modeling and neuro-navigated TMS reveal an active role of inferior frontal cortex in resolving sensory ambiguity.

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A much-debated question in the search for the neural underpinnings of consciousness is whether prefrontal cortex actively shapes conscious experience or, alternatively, serves only complementary functions such as evaluating and acting on the contents of perception. In this talk, I will present data from three experiments that investigated the role of prefrontal cortex in perceptual bistability. Human participants reported periodic changes in conscious experience that were induced by conflicting sensory information. Two functional magnetic resonance imaging experiments showed that prefrontal brain activity in inferior frontal cortex signals the conflict between conscious experience and available sensory information. In a third

experiment, inhibitory transcranial magnetic stimulation revealed that a disruption of neural activity in inferior frontal cortex leads to a decrease of conflict-driven changes in conscious experience. These results suggest that inferior frontal cortex plays a critical role in both the detection and the resolution of perceptual conflicts, pointing to a causal influence of prefrontal brain activity on the dynamic unfolding of conscious experience.

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Spontaneous Necker-cube Reversals are not that Spontaneous – An EEG Study

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During passive observation of the Necker-cube, our perception reverses between two interpretations. Despite the spontaneous character of reversals, theoretical approaches postulate slow destabilization of neural representations as a precondition for spontaneous reversals of ambiguous figures. The endogenous character of spontaneous reversals makes it difficult to separate neural processes preceding reversals from processes following. We addressed this with an onset-paradigm allowing high temporal resolution of reversal processes and focused on possible EEG correlates of perceptual destabilization preceding it.

We presented ambiguous Necker-cubes and contrasted EEG correlates of endogenous reversals with correlates of perceptual stability across two consecutive stimulus presentations. In a separate experiment, we contrasted exogenously induced reversals and stability of disambiguated cube variants. EEG contrasts before and during the reversal trials were compared.

We found the earliest EEG differences between reversal and stability trials already with the stimulus before a perceptual reversal at bilateral parietal and right-hemispheric electrodes. The traces start to differ about 1100 ms before a perceived reversal, become maximally different at around 867 ms ($p = 1*10\text{^}-5$, Cohen's $d = 1.15$) and stay different until shortly before onset of the reversed stimulus. No such patterns were found in disambiguated cube variants.

Our experimental paradigm allows to locate these EEG effects clearly before an endogenous reversal. Together with the absence of such effects before exogenous reversals, our findings probably reflect destabilized states of neural representations as a necessary precondition of an upcoming endogenous reversal. Spontaneous Necker-cube reversals are thus probably not as spontaneous as generally thought.

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Talk session 6. Perceptual Organisation

Mental Contour Tracing in a Neurodynamical Thalamo-Cortical Model of Attentional Binding

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Problem. Humans can extract visuospatial relations. In visual curve-tracing tasks, subjects covertly deploy attention, which propagates along the extent of an object to distinguish it from distractors (Jolicoeur et al., Memory & Cognition, 1986). Underlying neural spreading mechanisms incrementally bind visual items to form attended objects (Roelfsema et al., Nature, 1998). While experimental evidence favors the incremental grouping theory over the attentional spotlight theory, mechanistic understanding of how neural structures perform incremental binding by attention is still lacking.

Method. We present a dynamical neural model of thalamo-cortical interaction, which provides a computational account for how mental contour tracing is accomplished by incremental grouping mechanisms. The model entails pyramidal neurons with their basal and apical dendritic compartments representing the main site of information integration in primary visual cortex. Model neurons of higher-order thalamus are in coarse spatial registration with the cortical visual map. Recurrent thalamo-cortical interaction gates the apical-basal integration of target items depending on spatial attention.

Results. We demonstrate through computer simulations how the network model predicts a reliance on thalamic gating of cortical integration in concert with cortico-cortical activity spreading. Cortico-cortical interactions propagate local evidence of visual items to surrounding neurons with similar feature preference while active thalamic neurons provide complementary non-specific feature information to label cortical neurons with an incremental grouping signature. Our model generates testable predictions in support of the growth-cone hypothesis of attentional object selection (Pooresmaeili & Roelfsema, Current Biology, 2014) and that thalamus actively regulates information integration in cortical areas (Saalman & Kastner, Neuron, 2011).

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What do monkeys see behind the occluder?

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We have no trouble inferring that occluded portion of spiky objects are also spiky. To reveal what monkeys see when an object is occluded, we devised a free-choice paradigm. In most trials (85%), two unoccluded displays (sample and test), containing unoccluded shapes were presented in sequence, and animals had to make a correct 'same' or 'different' response to receive a juice reward. In the remaining 15% of trials, monkeys saw an occluded display as sample, and one of three unoccluded displays as test, and received a juice reward for making any choice. These three choices were: (1) A mosaic display without any completed contours; (2) A "likely completion" in which the statistics of the hidden portions are matched to the visible portions; and (3) An "unlikely completion" in which the statistics of the hidden portions were mismatched. Since monkeys were never explicitly trained on occluded displays, their choices in the free-choice trials represent an unbiased account of what they see behind the occluded display. Both monkeys were highly accurate in the unambiguous trials (88.5% across monkeys M1 and M2). More importantly, on the free choice trials, they responded "same" more frequently when they saw likely completions compared to mosaic and unlikely completions (% same response for likely, unlikely and mosaic: 53%, 34% and 3%, $p < 0.005$ on a chi-squared test for likely vs unlikely & likely vs mosaic). Taken together, our results demonstrate that monkeys indeed see what we see behind an occluder.

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The Frame Effect

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When two vertically aligned probes are flashed within a moving frame, they are seen with a large, illusory horizontal offset (Özkan et al, PNAS 2021). Here we describe what types of frames can produce, or fail to produce, this illusory separation. We first find that the frame effect holds for either smoothly or abruptly displacing frames even when the frame changes shape or orientation. Non-linear and even circular paths still support the frame-induced offset. The effect is driven by global not local motion and when there are competing, overlapping frames, the effect is determined by whichever frame is attended. There are however a number of constraints that limit the effect. A static anchor near the flashes may suppress the offset whereas an extended static texture does not. When the frame's path keeps one edge of the frame near the flash locations either by rotating around the flashes or flipping in 3D, the effect is reduced or eliminated. The effect is virtually abolished if the probes are continuously visible (as in Duncker's 1929 version) perhaps because the flashes reduce the buildup of evidence in favor of their physical location. These observations suggest that the criteria for what can act as a frame are quite broad, perhaps similar to those for apparent motion. The properties of the frame effect shown here make it a plausible contributor to visual stability across saccades.

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fMRI evidence of an orientation-invariant response to regularity in the human ventral visual stream

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The extrastriate cortex responds to visual symmetry and previous work has shown that this response is automatic: symmetry response is detected irrespective of whether we are attending to regularity or not. This could be linked to a representation of the regular pattern encoded at the "object-level" in the extrastriate cortex. If this were the case, we would expect regularity-sensitive areas to show an invariant response to properties such as axis of orientation.

To test this, we present dot patterns with 1-fold reflection and translation amid random configurations in a rapid event-related design while measuring fMRI responses. We manipulated the axis of orientation of the regular patterns (reflection, translation), such that these could either be vertical or horizontal, as well as participant's attention by performing either a regularity (i.e., reflection vs translation) or an orientation (i.e., horizontal vs vertical) discrimination task.

In line with previous studies, we observe symmetry selective responses in extrastriate visual areas. Furthermore, we see that: (1) these responses are not affected by attention to orientation or regularity visual features, (2) areas in the ventral stream show a regularity and

orientation invariant response, and (3) areas in the dorsal stream show an orientation selective response.

Our results suggest a possible dissociation between processing of orientation and regularity features in dorsal and ventral visual streams, respectively. Further analyses could clarify whether the orientation-selective response in dorsal visual areas results from a feedback processing mechanism whereby this feature is extracted following regularity processing.

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Underestimation of the number of occluded objects reveals limitations of perceptual completion

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In amodal completion, simple contours or patterns are filled-in behind occluding objects to allow for a complete representation of our environment. While there is support for completion of simple patterns from behavioral and neurophysiological studies, it is unclear if this extends to sparse, irregular patterns.

To this end, we studied the perception of numerosity in three experiments using either fully visible or partially occluded game boards with different numbers of randomly arranged game pieces. In the partially occluded condition, an occluder was floating in front of the game board to cover parts of it. In Experiment 1, observers accurately estimated the number of visible pieces, but heavily underestimated the number of pieces hidden by the occluder. Experiment 2 showed that this was not caused by an underestimation of the occluded area, because observers were able to accurately estimate the proportion of visible and occluded areas of the game board. Experiment 3 showed that the perceived number of hidden pieces was affected by the regularity of the visible pieces: When the visible pieces formed a line across occluded areas of the game board, underestimation of the number of hidden pieces was still present, but reduced. When the visible pieces formed a line separate from the occluded areas, underestimation was even more pronounced compared to irregular patterns.

Our results show that amodal completion is only accurate for simple but not for sparse, irregular patterns. This indicates that the representation of occluded parts of the environment underestimates the complexity of the environment.

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SPN (microvolts) = -1.669(W) -0.416 (Task) + 0.071

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Visual symmetry activates a network of brain areas in the extrastriate cortex. The extrastriate symmetry response generates an event related potential (ERP) called the Sustained Posterior Negativity (SPN). The SPN is a difference wave. After the P1 and N1 components, amplitude is lower at posterior electrodes when participants observe symmetrical compared to asymmetrical stimuli (Makin et al., 2012). Some symmetry types are more salient than others (Mach, 1886). Salience can be estimated with the Holographic Weight of Evidence model (van der Helm and Leeuwenberg, 1996). The holographic model provides a 'W-score' that ranges from 0 to 1. Previous work has found a linear relationship between W and SPN amplitude (Makin et al., 2016). Furthermore, the SPN is generated in all tasks but is selectively enhanced when symmetry is task relevant (Makin et al., 2020). We used the enforced research break imposed by COVID to compile all our SPN data sets into a public database (6674 SPN recordings from 2215 participant data sets in 40 projects). This is now available on open science framework (https://osf.io/2sncj/). Analysis of the whole database found that SPN (microvolts) = -1.669 (W) -0.416(Task) + 0.071. This regression model explained 33% variance in SPN amplitude. These effects were similar in both hemispheres. In contrast, peak P1 amplitude was not influenced by either W or Task. It would not be possible to draw these conclusions confidently from a single experiment: big data reveals the big picture.

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Talk session 7. Perceptual Decision making

Abstract neural choice signals during action-linked decisions

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Humans can make abstract choices independent of motor actions. However, in laboratory tasks, choices are typically reported with an associated action. Consequentially, knowledge about the neural representation of abstract choices is sparse, and choices are often thought to evolve as motor intentions. Here, we show

that in the human brain, perceptual choices are represented in an abstract, motor-independent manner, even when they are directly linked to an action. We measured MEG signals while participants made choices about the presence or absence of coherent visual motion. The motor response mapping was either known or unknown and changed on a trial-by-trial basis. Using multivariate decoding, we disentangled stimulus, perceptual choice and motor-response information with distinct cortical distributions. Choice representations were invariant to whether the response mapping was known during stimulus presentation, and they occupied distinct representational spaces from both stimulus and motor signals. Furthermore, their strength predicted decision confidence and accuracy, as expected from an internal decision variable. Our results uncover abstract neural choice signals that generalize to action-linked decisions, suggesting a general role of an abstract choice stage in human decision-making.

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Effects of a contextual probabilistic bias on visual motion perception and eye movements

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Expectation derived from past experience can influence visual perception and trigger anticipatory movements coherent with expected events. The growing literature on serial dependencies has revealed a complex pattern of effects of the previously observed stimuli and responses on the perceptual decision in the current trial. In particular, both attraction and repulsion effects have been reported, across different experimental conditions, whereby the current perception is biased either towards or away from the previous experience (e.g. a bar's orientation can be perceived as more or less tilted toward the previous bar's orientation).

In a number of recent studies we have a addressed the effect of a long-term probabilistic bias in the motion properties (direction, speed, acceleration) of a visual target (simple spot, RDK) upon motion perception and anticipatory tracking eye movements. By varying the stimulus properties and the task requirements across different experimental conditions, we report that 1) both anticipatory eye movements and motion perception judgments are efficiently modulated by the contextual probabilistic bias; 2) the contextual probabilistic bias modulates local perceptual and oculomotor serial dependencies weakly but significantly; 3) different behavioral responses can reveal attraction or repulsion effects with respect to the expectation (towards or against the probabilistic bias).

I will summarize all these results and discuss their possible explanation in terms of previously proposed models, namely optimal Bayesian integration and decoding, and the combination of the latter with efficient sensory encoding.

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Scene representations and categorization reaction times correlate in a time-window between 100 and 200 ms

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Humans are constantly processing scene information from their environment, requiring quick and accurate decision-making. Despite the importance of this process, it remains unknown which cortical scene representations are used in the decision-making process. Here, we approached this question empirically and algorithmically, using neuroimaging and computational modelling. For the empirical part, we collected electroencephalography (EEG) data and reaction times from human subjects (N=30) during a scene categorization task (natural vs. man-made). We characterized the time-window underlying these decisions by linking EEG and behavioural data via the distance-to-the-hyperplane approach: at every time point, we correlated reaction times with distances of scene representations to a natural/man-made hyperplane of a multivariate linear classifier trained on EEG data. Following signal detection theory we expected negative correlations to indicate a relationship between brain data and behavior. Indeed, we observed negative correlations between ~100 and ~200 ms after stimulus onset, suggesting that the neural processes in this time period produce scene representations that may feed into decision-making processes. Converging evidence was produced by computational modelling. We performed the distance-to-hyperplane analysis using human EEG data and model reaction times obtained from a recurrent convolutional neural network (rCNN). In line with the empirical results, rCNN reaction times correlated with human EEG data in the same time-window, between ~100 and ~200 ms. Together, these results indicate that scene representations arising between 100 and 200 ms contribute to perceptual decision-making, providing a previously missing link between neural activity and behaviour.

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Catecholaminergic neuromodulation and selective attention jointly shape visual perceptual decision making

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Attentional processes allow us to flexibly select incoming sensory information that is most relevant to us. Attended, versus unattended, sensory information is responded to faster and perceived more intensely. These effects have been related to gain modulation, i.e. the sharpening of neural representations through changes in the input/output relationship of neuronal networks. Theoretical and empirical work also suggests a role for neuromodulators, such as catecholamines and acetylcholine, in regulating global gain modulation via changes in cortical excitability. However, it remains unclear if, and if so how, attention and neuromodulator activity jointly modulate cortical excitability and consequently perceptual decision making. In this work, we tested this by pharmaceutically increasing levels of catecholamines (with atomoxetine) and acetylcholine (with donepezil), while at the same time manipulating spatial attention and measuring EEG. Specifically, 28 human participants performed a Gabor orientation discrimination task in which the likelihood that the Gabor was presented on the left/right of fixation was cued probabilistically. Drift diffusion modelling showed that increases in catecholamine levels as well as attention improved perceptual sensitivity by enhancing the rate of sensory evidence accumulation (i.e. drift rate). Interestingly, although attention and increased catecholamine levels both affected parietal evidence accumulation signals (CPP amplitude/slope), we observed separable effects of spatial attention and catecholamine levels (compared to placebo) on prestimulus cortical excitability and early sensory evoked responses. Increasing acetylcholine levels did not modulate task performance and neural activity in a consistent manner. These findings accentuate the important role of neuromodulators and internal state fluctuations in perceptual decision making.

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The effects of attentional suppression on sequential perceptual decisions

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Perceptual judgments are attracted towards features of stimuli seen in the immediate past, a phenomenon termed serial dependence. For example, decisions in orientation adjustment tasks are systematically biased towards the orientation of prior stimuli. This bias typically increases with uncertainty and depends on attention: only stimuli attended in the past affect decisions in the present. However, understanding the role of different attention components on serial dependence remains a challenge.

In this series of experiments, we manipulated spatial and feature-based attention during classic paradigms measuring serial dependence from orientation. To assess effects of spatial attention, trials on an orientation adjustment task were interleaved with an attention task, where observers had to ignore an irrelevant distractor. For feature-based attention, observers had to pay attention to oriented stimuli of given target colour, while ignoring stimuli of another irrelevant colour that appeared during the serial dependence task.

Overall, the engagement of attentional processes affected adjustment performance (e.g., precision and response times). However, stimuli that were irrelevant to the attention task, because their location or feature was ignored, produced no bias upon subsequent perceptual decisions. Instead, stimuli from the previous adjustment trial produced a robust serial dependence, despite the intervening attention task. Moreover, changes in the relevance of a feature right before a perceptual decision, further increased the bias toward prior relevant stimuli, likely reflecting a transient increase of uncertainty in task performance. We conclude that ignoring stimuli by discounting either spatial location or feature eliminates serial dependence effects.

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Updating contextual visual expectations

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The brain has the extraordinary capacity to construct predictive models of the environment by internalizing statistical regularities in the sensory inputs. The resulting sensory expectations shape how we perceive and react to the world; at the neural level, this relates to decreased neural responses to expected than unexpected stimuli ('expectation suppression'). Crucially, expectations may need revision as context changes. However, existing research has often neglected this issue. Further, it is unclear whether contextual revisions apply selectively to expectations relevant to the task at hand, hence serving adaptive behaviour. The present fMRI study examined how contextual visual expectations spread throughout the cortical hierarchy as participants updated their beliefs. We created a volatile environment with two state spaces presented over separate context blocks, controlled by an independent contextualizing signal. Participants attended a training session before scanning to learn contextual temporal

associations among pairs of object images. The fMRI experiment then tested for the emergence of contextual expectation suppression in two separate scenarios, respectively with task-relevant and task-irrelevant expectations. Behavioural and neural effects of contextual expectation emerged progressively within a context, accompanied by distinct neural profiles across the cortical hierarchy: expectation suppression appeared first in the insula, inferior frontal gyrus and posterior parietal cortex, followed by the ventral visual stream, and finally the early visual cortex. This applied selectively to task-relevant expectations. Taken together, these results suggest that an insular and frontoparietal executive control network may guide the flexible deployment of contextual visual expectations for adaptive behaviour in our complex and dynamic world.

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Talk session 8. Temporal processing

Intentional binding – Is it just causal binding? (A replication study of Suzuki et al., 2019)

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Intentional actions produce a temporal compression between the action and its outcome, a phenomenon known as intentional binding. However, recently, Suzuki et al. (2019) showed that temporal compression can be observed even without intentional actions. These data would challenge the concept of intentional binding profoundly. However, their results show a clear regression to the mean, which might have confounded the estimates of temporal intervals. To control for these effects, we presented temporal intervals block wise. Indeed, we found systematically greater compression for active than for passive trials, in contrast to Suzuki et al. (2019). In a second experiment, we aimed to replicate their experiment directly. We failed to replicate their results and again observed stronger temporal compression for the active than passive trials. Our findings reinforce the theory that intentions cause temporal binding and demonstrate that this idea is not challenged by the paradigm of Suzuki et al. (2019). Furthermore, our results indicate that the temporal compression is not affected by the predictability of the active and passive actions.

Suzuki, K., Lush, P., Seth, A. K., & Roseboom, W. (2019). Intentional binding without intentional action. Psychological Science, 30(6), 842-853.

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Visual integration plays a critical role when processing motion through periods of occlusion

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Visual information is interrupted frequently due to occlusion, eyeblinks, and saccades. When objects are moving it is particularly challenging to bridge these visual gaps, as position information and motion trajectories have to be updated. In a series of behavioural studies, we examined what mechanisms support motion processing through dynamic occlusion. We used behavioural data in conjunction with eye-tracking data to address three research questions. First, we tested how accurate participants are at estimating the motion trajectory of an object that is visible pre- and post-occlusion. Second, we investigated how well participants can estimate the position of an object while it is behind an occluder without seeing it reappear. Third we examined the role of temporal estimation in processing motion through dynamic occlusion. Our results showed that when the object reappeared, participants accurately detected if the object slowed-down or sped-up during occlusion. However, without object reappearance, participants performed poorly when estimating the object's position during occlusion, with performance decreasing as time behind the occluder increased. This indicates that integration of visual information pre- and post-occlusion is important for successfully estimating occluded motion. The eye-tracking data revealed that people are using different strategies ranging from tracking the object through occlusion to estimating the time of reappearance while fixating. Overall, these findings provide new insights into how we bridge motion across visual gaps and perceive the visual world as continuous.

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Manipulating stimulus recognition via visual crowding shortens perceived duration

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The perceived duration of a stimulus is reduced by a number of non-temporal stimulus properties, e.g. increasing eccentricity or reduced stimulus visibility. In two experiments, we investigated how reduced stimulus recognition alters perceived duration. Stimulus recognition was manipulated by visual crowding, which is the reduced recognition of stimuli surrounded by nearby flankers. If low level features (e.g., density, size) determine time estimation, one would assume overestimation of flanked compared to

isolated stimuli. If higher level visual processing determines time estimation, one would assume temporal underestimation of flanked stimuli, due to reduced recognition. In Experiment 1 (n = 23), participants indicated whether the duration of a comparison stimulus (target letter) of varying duration was shorter or longer than a centrally presented standard stimulus of constant duration. Comparison stimuli were presented isolated or flanked with a small or large target-to-flanker spacing in 3° or 9° of eccentricity horizontally. An eye tracker ensured fixation. The results show that stimuli presented with a small spacing are perceived as shorter compared to isolated or largely spaced stimuli, providing initial indication that reducing stimulus recognition shortens perceived duration. Experiment 2 (n = 23) comprised a dual-task design, in which subjects additionally identified the target letter. Results confirmed manipulation of crowding: letter recognition for flanked targets was significantly reduced. Conversely, there was a significant duration underestimation of flanked targets. Thus, perceived duration seems to be compressed by impaired stimulus recognition.

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Rhythms of sensory representations

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Visual attention fluctuates over time and modulates information processing periodically: theta frequency (4-7 Hz) during spatial exploration, and alpha frequency (8-12 Hz) when attention is sustained at a given location. We hypothesized that such rhythms in behavioral performance accompany fluctuations in the quality of sensory representations, and specifically, (1) changes in the tuning to relevant features, and/or (2) enhancement (gain) of the target stimulus feature, and/or (3) suppression of irrelevant features. We tested this hypothesis using a psychophysics reverse correlation paradigm in which participants were instructed to deploy endogenous (voluntary) attention across two possible spatial locations (bottom left or right quadrant). Participants were asked to discriminate the gap position of a cued (valid; 2/3) or uncued (invalid, necessitating attentional reorienting; 1/3) Landolt-C. In the same trial, after a variable delay, two noise patches were presented at the same two locations, and participants had to detect the presence of a Gabor in each patch independently (50% present). The first discrimination task was used to manipulate attention while the subsequent detection task probed attention at each location and delay. Our results replicated the rhythmic fluctuations of sensitivity (d') found in previous experiments. For sustained attention, d' fluctuated at the alpha frequency, and when attention was reoriented (exploration) d' fluctuated at the theta frequency. Critically, the results of the reverse correlation analysis suggest that the representations of irrelevant features were rhythmically suppressed during sustained attention, and the relevant target feature was rhythmically enhanced during exploratory attention.

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The spatio-temporal organization of alpha brain oscillations shape visual perception across the retinotopic space

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The phase of low frequency (4-7Hz, theta; 8-12Hz, alpha) brain oscillations modulate perceptual performance periodically over time. We hypothesize that not only the temporal dynamics of brain oscillations but also their spatial organization within the visual cortex have a functional role on perception. In a first experiment, human participants (n=15) performed a psychophysical task with simultaneous EEG recordings. Theta and alpha brain oscillations were induced by a peripheral disk oscillating in luminance (30s of inducer stimulus; 4, 6, 8 and 10Hz), while participants performed a low-contrast target detection task (50% detection). The targets were presented at random delays during the inducer presentation, at one of three possible eccentricities between a fixation cross and the inducer. EEG analyses showed that the disk induced complex brain oscillations, composed of the induced frequency and its first harmonic, in the visual cortex. We further showed that the inducer modulated detection performance periodically at each target position and frequency. Interestingly, the optimal phase for visual perception (maximal performance) shifted as a function of target eccentricities for 8 and 10Hz brain oscillations, with a respective propagation speed of 0.08 and 0.05 m/s. In a second experiment, participants (n=14) performed the same task, except that the inducer was a checkerboard annulus around fixation, pattern reversing at 10Hz. Similar to the first experiment, the optimal phase shifted as a function of distance from the annulus. Our results demonstrate that induced alpha oscillations are propagating across the human visual cortex, leading perceptual cycles to travel across the retinotopic space.

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Neuronal pattern similarities underlie stable visual perception in the human visual cortex

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In the search for a neuronal signature of perceptual awareness, the magnitude of the neural response is commonly considered a critical factor in the process. However, a major challenge to this notion is the striking phenomena of rapid visual adaptation, in which the amplitude of the response dramatically declines within 500 ms of the visual stimulation, while the visual input and the conscious experience it elicits remain stable. Here we examined the hypothesis that the perception of a visual stimulus is determined and sustained by the activation patterns across neuron populations, and the relational geometry defined by the similarities between these pattern, rather than by their average magnitude. Visual images of familiar faces and places were presented for 1.5 seconds to 13 patients implanted with intra-cranial electrodes for clinical purposes. High-order visual cortex displayed strong, ignition-like responses that rapidly declined despite the persistent stimulus. By contrast, the profiles of the multi-electrode activation patterns and their relational geometry- i.e. the similarity distances between different stimuli representations, remained sustained. These results are compatible with the hypothesis that visual perceptual content is reflected in the multi-site pattern of neuronal activations, and by its associated similarity-distances profile, in the human visual cortex.

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Talk session 9. Perceptual memory & learning

The Relationship between Shape Features, Naturalness Perception and Visual Memory

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Shape features such as roundedness and symmetry may affect how well we remember shapes and how natural we perceive them. Although theories such as independent components, bitten effect theory, fruit theory and predator detection theory attempted to explain how shape features are linked with memory and naturalness, there are no studies that explored the threefold link between shape features, memory and naturalness. In this study, we examined how the 2D shape attributes; edge number, concavity, roundness and uniformity affect the memory performance and naturalness perception. We designed a behavioral experiment where participants viewed shapes that vary in shape features. 20 participants performed a method of adjustment task to match the remembered shape using sliding bars that correspond to different shape features and a naturalness survey. Correlation analysis and repeated measure ANOVA revealed that edge count, concavity and roundness significantly affect memory performance. Participants remembered edge number and concavity features less accurately for highly rounded shapes. They remembered the concavity of heptagons more accurately. Our results also show that increased naturalness perception correlates with high roundness, low edge numbers and low concavity. Finally yet importantly, we found that shapes that are perceived less natural are better remembered. These findings inform about the influence of low-level features and a semantic inference that is naturalness on visual memory performance of shapes. We conclude that efficient resource allocation on selective attention may play a role in naturalness perception and visual memory.

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Individual differences in face identification performance: Can matching predict face learning efficiency?

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Within-person variability in appearance (e.g., changes in hairstyle and expression) makes it challenging to decide whether images of unfamiliar faces depict the same person or different people. Witnessing the ways in which a face varies in appearance facilitates learning, allowing recognition across highly variable images. We examined individual differences in unfamiliar face identification and whether these individual differences predict the efficiency of face learning. In Study 1 (N=210) participants completed four unfamiliar face identification tasks that varied in task demands (sorting, same/different, line-up). One week later, participants completed a second version of the same tasks. Individual differences in sensitivity and response bias were stable across time and tasks, ps<0.001, and loaded unto separate components. In Study 2 (N=148), we presented stimuli simultaneously vs. sequentially, introducing memory demands. We replicated the results of Study 1 (ps<0.003). In Study 3 (N=156) we investigated the extent to which unfamiliar face identification performance predicts the efficiency with which one learns a new face. Participants completed 2 unfamiliar matching tasks, 2 face memory tasks and then

were asked to recognize novel images of a newly learned identity after viewing 1, 3, 6, or 9 images. Face learning efficiency was measured via the difference in the slope of recognition sensitivity following each of the learning conditions Unfamiliar face matching influenced the face learning intercept, but not the slope of face learning (i. e., improvement in d' was similar across matching abilities). The results have implications for applied settings and theoretical models.

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A matter of availability: neural representations of task-relevant stimulus features are sharper when stimuli are memorized rather than perceived.

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Our visual environment is relatively stable over time and an optimized visual system ought to capitalize on this by not devoting any representational resources to objects that are still present. Subjective experience, however, suggests that externally available (i.e., perceived) information is more strongly represented in neural signals than memorized information. To distinguish between these possibilities, we use EEG multivariate pattern analysis to quantify the strength of representation of task-relevant features (color or spatial frequency) in anticipation of a change-detection task. Perceptual availability was manipulated between experimental blocks by either keeping the stimulus on the screen during a two second delay period (perception) or removing it shortly after its initial presentation for the same time period (memory). We find that task-relevant (i.e., attended) memorized features are more strongly represented than irrelevant features. More importantly, we find significantly weaker representations for available (perceived and attended) features than for unavailable (memorized and attended) features. Contrary to what subjective experience suggests, our findings demonstrate that vividly perceived and attended stimuli elicit weaker neural representations (in terms of detectable multivariate information) than stimuli maintained in visual working memory. We hypothesize that an efficient visual system spends little of its limited resources on the internal representation of information that is externally available anyway.

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Electrophysiological Markers of the probability cueing suppression: statistical learning of distractor locations and inter-trial modulation

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Visual search performance is facilitated when the singleton distractor occurs at a high probability location where the distractor occurred frequently in the past, compared to locations where it rarely occurred. Additionally, some studies found search becomes slower when the target appeared at the location of the preceding distractor (coincident condition). However, the underlying neural mechanisms have not been closely examined. Here, we used lateralized event-related electroencephalogram (EEG) potentials and lateralized alpha power (8-12 Hz) to shed further light on the temporal dynamics of the distractor suppression modulated by inter-trial and statistical learning of distractor locations. Adopting an additional singleton paradigm (N = 21), we observed a stronger suppression (shorter RTs) when the color-defined distractor appeared at a specific frequent location than other rare locations in search displays. We found slower RTs in the coincident versus the non-coincident condition mirrored by the larger amplitude of the SPCN component, suggesting the distractor-target inter-trial mechanism needs further access to visual working memory in a context scene. However, the lateralized alpha power (8-12 Hz) reflects no anticipatory suppression of spatial attention based on probability cueing of distractor locations. Our findings thus provide new neurophysiological evidence for individuals' attention modulation by the statistical learning of distractor locations and inter-trial effects.

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Visual guessing as counterfactual metacognition

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When we don't know what we've seen, we guess. How? Many empirical and modeling approaches assume human guessing is random and can be characterized as samples from either (a) a uniform distribution of feature values, or (b) a distribution biased towards the prevalence of those features in the world. However, a third approach might involve (c) "self-representation"—modeling not only likely features in the world, but also one's own capacity to perceive those features. Here, we pit these

approaches against one another and find that guesses derive from a self-representing strategy, reflecting intuitive internal estimation of one's own perceptual capacities. Adult observers performed a visual working memory task in which either two colored discs (E1) or three oriented arrows (E2) simultaneously appeared at isoeccentric locations for either 0, 16, 33, 66, or 132ms, before being masked by randomly oriented arrows or colored discs. Measuring "guess" responses on 0ms trials revealed a mismatch between the popular uniform-guess account and actual behavior: for both color and orientation, observers' guess patterns were characterized by systematic non-uniformities. Crucially, in Experiment 2, observers were less likely to guess higher-precision (cardinal) orientations relative to lower-precision (oblique) orientations, reflecting a bias to select feature values with low prior probability and low internal precision (as if reasoning "that's something I would miss"). Our results reveal that, rather than sampling uniformly over a given feature dimension, human guessing forms the complement of perceptual precision, reflecting strategic, counterfactual metacognition.

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Conceptual associations generate sensory expectations throughout the visual system

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Perception relies on prior knowledge. In line with this hypothesis and with predictive processing theories, previous studies have shown that surprising stimuli are associated with an enhanced sensory response, possibly signifying prediction error signals. However, while such sensory prediction errors have been demonstrated for violated expectations pertaining to specific sensory stimuli, expectations often generalize beyond specific stimuli. Here we asked the question whether learning of arbitrary conceptual associations would lead to the formation of sensory predictions. To this end we exposed participants to arbitrary word-word pairs (e.g., "man" – "house") repeatedly, thereby creating an expectation of the second word, conditional on the occurrence of the first. Then, in a subsequent session, we exposed participants to word-picture pairs, while measuring fMRI BOLD responses. Here, all word-picture pairs were equally likely, but half of the pairs conformed to the previously formed conceptual (word-word) associations, whereas the other half violated these associations. Results showed increased sensory responses throughout the ventral visual stream, including primary visual cortex, to object pictures that violated the previously expected word associations. Therefore, our results demonstrate that expectations formed during exposure to word-word associations have consequences for sensory processing of object images, resulting in an increased sensory response to visual objects that violate conceptual expectations. In sum, our data suggest that predictions and the resulting prediction errors extend beyond sensory regularities and generalize across domains, such as using recently acquired conceptual associations to generate perceptual priors.

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Talk session 10. Attention II

Temporal and organisational parameters of preparatory search template activation

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Visual search for known objects is guided by attentional templates (working memory representations of target features), which are activated prior to search. Here we will give an overview over a series of experiments we conducted to investigate the temporal dynamics of such preparatory template activation by means of a rapid serial probe presentation paradigm (RSPP). Search displays, containing a pre-defined colour target among five differently coloured distractors, were presented every 1600ms. A continuous stream of probe displays was presented every 200ms between successive search displays. Probe displays contained a (target or distractor) colour singleton among five grey items. N2pc components (electrophysiological markers of attentional capture) were measured separately at each probe's temporal position to determine when in time - prior to search - attentional templates are activated to guide selection. We found that distractor-colour probes never triggered N2pc components, indicating that they were not systematically attended. However, target-colour probe N2pc amplitudes increased during the preparation period and were largest for probes directly preceding the next search display. This pattern of results suggests that attentional templates are activated (colour-)selectively and transiently during the preparation for individual search episodes. In further experiments we can now demonstrate that this transient template activation pattern i) flexibly adjusts to temporal task demands when preparation times change, and that it persists during ii) multiple (two or three) colour search, iii) independently of whether the upcoming target colour is predictable or random, and iv)

during singleton search when salience signals would theoretically be sufficient for target detection.

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Asymmetric learning of dynamic spatial regularities in visual search: facilitation of anticipated target locations, no suppression of predictable distractor locations

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Static statistical regularities in the placement of targets and salient distractors within the search display can be learned and used to optimize attentional guidance. Whether statistical learning also extends to dynamic regularities governing the placement of targets and distractors on successive trials has been less investigated. Here, we applied the same dynamic cross-trial regularity (one-step shift of the critical item in clock-/counterclockwise direction) either to the target or a distractor, and additionally varied whether the distractor was defined in a different (color) or the same dimension (shape) as the target. We found robust learning of the predicted target location: processing of the target at this (vs. a random) location was facilitated. But we found no evidence of proactive suppression of the predictable distractor location. Facilitation of the anticipated target location was associated with explicit awareness of the dynamic regularity, whereas participants showed no awareness of the distractor regularity. We propose that this asymmetry arises because, owing to the target's central role in the task set, its location is explicitly encoded in working memory, enabling the learning of dynamic regularities. In contrast, the distractor is not explicitly encoded; so, statistical learning of distractor locations is limited to static regularities.

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Dynamic behavioural and physiological measures of audience immersion in film and television

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Film can captivate and immerse audiences over extended timescales, where individuals expend mental resources attending to and representing on-screen events. As film is dynamic, it is likely that immersion fluctuates over the course of a viewing experience, in response to low-level visual features (e.g. dynamic range) and high-level properties such as narrative.

Here, we present results from two experiments which aim to validate a set of continuous behavioural and physiological measures of immersion (dual-task reaction times, heart rate, and skin conductance). In these experiments, we compare each of our continuous measures to self-reported engagement across a series of short television and film clips. Experiment 1 ($n = 164$) demonstrates that dual-task reaction times are strongly related to self-reported narrative engagement (in particular, emotional engagement with the story). In Experiment 2 ($n = 48$), we find that synchrony in heart rate across participants is indicative of self-reported narrative engagement (both attentional and emotional engagement). We do not find a relationship between skin conductance and self-reported engagement.

We discuss the impact of this work for vision science in informing our understanding and measurement of continuous fluctuations in attention. We also discuss the practical applications for filmmakers and content creators, and how this approach may be used to inform future content design.

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Examining the relationships between internal noise and different types of attention

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Considerable differences in attentional effects exist among individuals. These include both benefits (i.e., better performance when the target appears at a validly cued compared to a non-cued location) and costs (i.e., worse performance when the target appears at an invalidly cued compared to a non-cued location), and in different tasks. These individual differences have mostly been attributed to post-perceptual factors such as working-memory capacity. Here, we examined whether a perceptual factor – the internal noise level – is related to inter-individual variability in attentional effects. Internal noise was estimated using the double-pass procedure combined with an external noise paradigm, and computational modeling. We also measured the effects of spatial attention in an acuity task: participants reported the side of a square on which a small aperture appeared. Central arrows were used to direct sustained attention and peripheral cues to engage transient attention. Additionally, temporal attention was measured using the attentional blink paradigm. We found reliable correlations between individual levels of internal noise and the effects of both types of spatial attention, albeit of opposite directions: positive correlation with sustained attention and negative correlation with transient attention. When participants were split into groups by internal noise level (low/high), we found that participants with high internal noise displayed a significant cost of

attending the wrong location when deploying sustained attention. Additionally, we found that internal noise levels predicted attentional blink magnitude. These findings demonstrate that internal noise can predict individual differences in the effects of various types of attention.

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The influence of task-relevance and awareness on reward-driven attentional capture

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During search for shape-singleton targets that stand out by their shape among more shape-homogenous distractors, distractors carrying a color associated with reward can capture visual attention, seemingly despite being task-irrelevant and not salient, indicating that reward-driven capture could be different from top-down and bottom-up attentional guidance. However, if association with reward increases a color's salience – as sometimes assumed –, a rewarded color would stand out as a singleton compared to surrounding stimuli with colors not or less associated with reward. Consequently, distractors carrying a rewarded color could match an observer's attentional control setting during search for (shape) singleton targets. To test this possibility, we used the classical design for investigating reward-driven capture, with a learning block for the acquisition of color-reward associations. However, besides a singleton-search task, we added a feature-search task as an additional transfer block. While we found reward-driven capture during singleton search (replicating previous results), there was no evidence for reward-driven capture during feature search. Additionally, we registered participants' awareness of the reward-color association. Unexpectedly, we found that even during singleton search, reward-driven capture was restricted to participants who did not notice the reward-color association, suggesting that reward-driven attentional capture depends not only on task-relevance but also on unawareness of the now irrelevant reward-color association. We conclude that the influence of reward on attentional guidance is more complex than previously thought, with interactions of task relevance and awareness that warrant further research.

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When do we find a third neural response to visual symmetry?

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The human visual system is tuned to symmetry, and the neural response to visual symmetry has been well studied. One line of research measures an Event Related Potential (ERP) component called the Sustained Posterior Negativity (SPN), an increased negativity at posterior electrodes when participants see symmetrical patterns compared to asymmetrical patterns. In line with fMRI results, EEG source localisation confirms that the SPN is generated by two sources in the left and right extrastriate cortex. Furthermore, recent research revealed a third source in response to symmetrical patterns located external to the visual cortices, peaking at approximately 600 ms. This third symmetry response was only generated in conditions where symmetry was 1) task relevant and 2) salient. We will test if these findings are reliable by running source localization analysis on all suitable data sets from the complete Liverpool SPN catalogue (an online repository of SPN research with 2215 participants https://osf.io/2sncj/). Specifically, we predict that less variance will be explained by a two-dipole model in experiments where participants classified regularity (hypothesis 1), and when the third dipole is present, amplitude will correlate with that of the sensor-level SPN (hypothesis 2). If these predictions are confirmed, we could confidently claim to have discovered a new brain response to visual symmetry.

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Talk session 11. Colour

Projective Colorimetry

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Colorimetry is objective measurement of light's spectrum through fixed spectral functions. Color matching functions XYZ are basis functions for building trichromatic color space representing ideal colorimetric observer. In XYZ color space, chromaticity diagram xy corresponds to the projective plane P2(R); it is a two dimensional indexing of light's colorfulness through central projection onto the plane X+Y +Z=1. However, subjective perceptual attributes of color such brightness, saturation and hue are ill defined in colorimetric space and chromaticity diagram. We propose to build color spaces as three dimensional projective spaces E=P3(R)=P(R4) or the projective space constructed inside the real vector space of dimension four. A collinearity equivalence relation reduces the dimension to three and shapes color space as a stacking of proportional surfaces. Vector space R4 is based on four spectral functions instead of three. The fourth function is interpreted as the projective direction of the projective frame and can change with the adaptation state of the observer or along neural visual pathway. We show how this interpretation potentially relates objective and subjective measurement of color through projective transformation and provides a new relationship between physical, physiological and perceptual color spaces by three examples. 1-Chromaticity diagram is defined as a projective

subspace of E in physical frame. 2-Yilmaz's color solid relating light's radiance to object's reflectance independently of the light source is described for illustrating physiological frame. 3-A model of the double cone is proposed, illustrating the principle of perceived colored shadow described by Monge.

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Large-scale color biases in the retinotopic functional architecture are shared across human brains

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Despite the functional specialization in visual cortex, there is growing evidence that the processing of chromatic and spatial visual features is intertwined, possibly reflecting the significant role of spatial information in many color vision computations. It is unknown, however, if the brain's integrated coding for retinotopic space and chromatic stimulus features is shared across different human observers or if, alternatively, coding is idiosyncratic to each individual. In the present study, we therefore investigated if it is possible to predict the color a person was seeing using a linear classifier that has never been trained on chromatic responses from that same brain, solely by taking into account: (1) the chromatic responses in other individuals' brains and (2) commonalities between the spatial coding in brains used for training and the test brain. We applied shared response modeling (SRM) to fMRI responses to purely spatially defined and achromatic retinotopic mapping stimuli recorded from human brains in order to transform individual independently measured color responses to a common functional space. Cross-validating linear classifiers in a leave-one-subject-out scheme, we were able to predict the color (and luminance) of stimuli seen by an observer simply based on other subjects' activity patterns in the common spaces in areas V1-V3, and mid-level regions hV4 and LO1. By predicting voxel responses across brains from SRMs, further analysis revealed systematic, region-specific, large-scale retinotopic biases for the different colors that may at least partially explain the agreement in the way that different brains represent identical color stimuli.

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Seeing colour for the first time: color perception in achromatopsia patients following gene augmentation therapy

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Is your red my red? This is a question first year philosophy students are frequently confronted with. Here, we had the opportunity to ask an even more intriguing philosophical question: how will a person who has never seen colour before perceive colour for the first time? CNGA3-achromatopsia is a congenital hereditary disease in which cone dysfunction leads to patients having rod-photoreceptor-driven vision only, seeing the world in blurry shades of grey. We studied colour perception in four CNGA3-achromatopsia patients following monocular retinal gene augmentation therapy in which an intact copy of the CNGA3 gene (driven by a cone-specific opsin promoter) was delivered using a viral vector. Following treatment, patients failed in standard colour testing, but consistently reported red as glowing, specifically on a dark background. We have conducted a gamut of tests to better define this subjective description. We evaluated patients' perceived colour lightness, chrominance detection and saliency, comparing their treated with their untreated eye. While colour lightness was generally similar between eyes, chrominance detection was evident only in the treated eyes. In a search task, long response times, which were further extended with array size, suggested low saliency to this new colour percept. We suggest that treated CNGA3-achromatopsia patients can perceive colour, although in a manner which is limited and very different from normally-sighted controls. We discuss the retinal and cortical obstacles that might explain this perceptual gap and suggest a path for visual training given these results.

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Linear additivity of chromatic and achromatic inputs in primary visual cortex

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Primary visual cortex (V1) receives one achromatic [L+M +S] and two colour-opponent [L-M and S-(L+M)] inputs from the lateral geniculate nucleus. Neuronal populations in V1 could respond independently to the stimuli along these three colour directions, meaning that responses to combinations of them would be linearly additive. We therefore tested whether BOLD responses to stimuli specified along the L-M, S-(L+M) and L+M+S directions were combined linearly in V1.

During fMRI scans, we presented L-M and S-(L+M) target gratings on a background consisting of an array of dynamically modulated checks (L+M+S contrast). We measured responses to five contrasts of L-M and S-(L+M) combined with five L+M+S contrasts of the background. The responses were shown to be consistent with linear

combinations of L-M and L+M+S, and S-(L+M) and L+M+S contrasts. We then fixed the background contrast to 50% and measured responses to combinations of five contrasts of the chromatic targets along L-M and S-(L+M) directions. In this case linear combination held over a large range of the contrasts presented, but at high contrasts for both directions signals varied less than predicted by linear combination.

We show the three inputs to V1 are processed largely independently with responses showing little evidence of interaction. However, the non-linear response to high chromatic contrast combinations may be indicative of chromatic mechanisms that are specific to V1 and not its inputs.

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The colours of images preferred by individual voxels delineate visually responsive brain areas

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Visually responsive brain areas are anatomically segregated on the cortical surface according to their stimulus preferences. We used the unique 7T fMRI Natural Scenes Dataset (NSD; Allen et al. 2021, Nat. Neurosci., 25, 116-126) to investigate the colours of images evoking high responses at different cortical locations. The NSD consists of data from eight participants who each saw 9000 – 10000 images from the Common Objects in Context database. For each voxel we calculated a 'voxel preferred image', a scaled weighted average of all the RGB images viewed, weighted by the average voxel response to each image. The resulting RGB image for each voxel prioritizes the commonalities of the images that best activate it; its colour reflects both the voxel's intrinsic colour preference and the colours associated with other preferred image features in the stimulus set. We plotted the voxel-preferred images at the corresponding voxel locations on cortical surface maps and found clear spatial organization of the colours of preferred images. Split-half reliability analyses revealed strikingly similar patterns of the colours of voxel preferred images across the cortical surface from each half of the data, and patterns were also similar for different participants. We found that the boundaries between clusters of voxel-preferred images with similar colours tend to coincide with atlas-based delineations between visually responsive brain areas, but also that there is reliable and interesting heterogeneity within visual areas. The colours of voxel-preferred images may provide a useful method for delineating clusters of voxels with common visual functions.

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Effects of the directional and spectral distribution of daylight on colour gradients

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Human vision is attuned to the statistical regularities of daylight through evolution and experience. Therefore, daylight measurement in natural scenes has great potential value for advancing our understanding of visual perception. Despite the solar radiation being more or less static, the effective daylight's spectral power distribution (SPDs) can dramatically differ depending on location, direction, time, or weather conditions due to complex light-material interactions. Here, we present a portable spectrometering system that can capture the high-dynamic-range light environment with perception-based temporal, spatial, directional, and spectral resolutions. The method relies on measuring the SPDs on six faces of a miniature cube centred at any measurement position to estimate up to the first-order light field. We applied our method to collect local light fields in a rural location near Delft at a 5-minute interval from sunrise to sunset on a sunny day and a cloudy day. We found that the light-vector directions were wavelength-dependent; the shorter the wavelength, the higher its altitude. On the sunny day, the light-vector azimuths barely varied as a function of wavelength, while those for the cloudy day did. The results can be explained by scattering mechanisms such as Rayleigh scattering. Via spectral rendering using our light field data, we show that wavelength-dependent light-vector directions can induce complex colour gradients for object shading, even for spectrally neutral surfaces. Our cubic method opens up novel opportunities for capturing the differential contributions of the effective diffuse and directed daylight field resulting from sky and sunlight interacting with (objects in) the environment.

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Talk session 12. Object Perception 1

Visual transients improve object recognition of CNNs in sketches but not in natural images

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Human vision is mediated by neural responses to luminance edges in space and time. Many vision models including classical Convolutional Neural Networks (CNNs) only mimic spatial visual processes, assuming static visual inputs over short time periods. However, due to small eye jitters, i.e. fixational eye movements (FEMs), the eyes are constantly moving which introduces visual transients over time that emphasize luminance edges. Here, we have explored whether CNNs benefit from FEM-induced visual transients in a simple object recognition task. For this, we have trained two CNNs on image classification with ImageNet. We trained the first CNN (CNN-static) on standard grayscale images. We trained the second CNN (CNN-active) on edge images that emerge from FEMs (i.e. ocular drift) if we filter the actively-sampled grayscale images with filters that mimic the spatiotemporal response characteristics of retinal ganglion cells. We find that the image classification accuracy of CNN-active is lower compared to CNN-static. Since the image classification performance of classical CNNs generalizes poorly to more abstract images like sketches, we additionally tested how well the performance of both CNNs generalizes to ImageNet-Sketch. Conversely, we find that CNN-active outperforms CNN-static at a low level. We conclude that FEM-induced visual transients do not facilitate object recognition of classical CNNs on natural images but potentially do so on more abstract images such as sketches. These findings might indicate that the early visual system encodes spatial information in space and time mainly to reduce energy-consumption at the cost of losing relevant information related to natural images.

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Neural model for the responses of IT neurons during anorthoscopic perception

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Humans are able to recognize objects that are presented sequentially, translating them behind a narrow slit (anorthoscopic perception). This implies that never the whole object is visible at the same time. This capability is not easy to explain using standard deep neural network (NN) models of visual object recognition. METHODS: We present a deep NN that recognizes anorthoscopically presented body shapes, and reproduces properties of IT neurons during anorthoscopic perception (Bognar & Vogels, 2021). The initial model layers correspond to a standard deep NN model (VGG16). The intermediate levels are formed by special local nonlinear recognition units, which assess the similarity of features that are highly visible in the training and test stimuli, followed by holistic recognition units that integrate information over large parts of the figure. Position-invariance is accomplished, combining weight sharing with maximum pooling of the holistic detector responses. RESULTS: The model recognizes shapes from sequentially presentation through a slit; it reproduces the following properties of IT neurons: (i) shape-selective neural responses to the full figure as well as to presentations through a slit; (ii) low influence of the sequential order of the slit views; (iii) partial transfer between activation patterns for vertical and horizontal slit views. CONCLUSION: By integration of mechanisms that prevent interference between slit and object features, hierarchical NN models might account for object recognition during anorthoscopic perception.

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Emergence of topographic organization in a non-convolutional deep neural network

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A predominant aspect of the primate visual system is its topographic organization. From hypercolumns in early visual cortex to higher visual areas selective for faces, objects or places, the spatial location of neurons in the cortical sheet is predictive of their feature selectivity. How and why this organization emerges remains a topic of debate. While computational models are important for testing out various hypotheses, the neural networks most commonly used in vision rely on convolutional layers. These prohibit meaningful studies of topographic organization as they enforce identical feature selectivity at all spatial locations. Here, we report progress in using spatially-regularized non-convolutional deep neural networks for modelling primate vision. Trained on large-scale image recognition, these networks exhibit topographic organization. For example, early layers learn smooth orientation selectivity maps similar to the hypercolumn organization of V1. At the same time,

this emergent orientation selectivity is more varied in the layer centre, reminiscent of cortical magnification observed in V1. These results suggest a functional origin of cortical magnification that arises due to higher object-related information density in the central visual field. In addition, faces and objects are processed in different spatial locations of higher layers. These findings pave the way for using deep neural networks to study the origins of topographic organization in the visual system.

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Category-orthogonal object features guide information processing in recurrent neural networks trained for object categorization

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Recurrent neural networks (RNNs) have been shown to perform better than feedforward architectures in visual object categorization tasks, especially in challenging conditions such as cluttered images. However, little is known about the exact computational role of recurrent information flow in these conditions. Here we test RNNs trained for object categorization on the hypothesis that recurrence iteratively aids object categorization via the communication of category-orthogonal auxiliary variables (the location, orientation, and scale of the object). Using diagnostic linear readouts, we find that: (a) information about auxiliary variables increases across time in all network layers, (b) this information is indeed present in the recurrent information flow, and (c) its manipulation significantly affects task performance. These observations confirm the hypothesis that category-orthogonal auxiliary variable information is conveyed through recurrent connectivity and is used to optimize category inference in cluttered environments.

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Organization of object space in human occipitotemporal cortex

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Objects are represented in the occipitotemporal cortex (OTC) but it has proven difficult to distill an integrative view of the complex functional organization of these regions. Recently, Bao et al. (2020, Nature) proposed a characterization of object space in monkeys in which OTC is organized as a space with two main dimensions, stubby-spiky and animate-inanimate. However, the definition of these two dimensions might be confounded by selectivity for faces and bodies, for example, face stimuli were mostly stubby. To dissociate individual dimensions that might characterize object space, we prepared a novel set of stimuli including images of animates (face and body) and inanimates (natural and man-made) with a comparably wide range of aspect ratios in each of these four categories. We obtained fMRI and deep neural networks (BigGAN) responses to stimuli and employed multivariate pattern analyses to examine the similarity of representational space between OTC, BigGAN, and models of animacy or aspect ratio. Results showed that object space in BigGAN and most category-selective regions was significantly better explained by the animacy rather than the aspect ratio model and brain decoding resulted in higher accuracy for animate-inanimate classification than stubby-spiky. In addition, we observed transitions in the representational content along the anatomical posterior-to-anterior axis in OTC. Our findings suggest that object representations strongly rely on the animacy aspect and the distinction between faces and bodies, but not on aspect ratio and there is not a unique object space along the ventral visual pathway, a very different organization compared to previous proposals.

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How do children view the world? The temporal dynamics of visual perception in preschool age children

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Recent neuroimaging work has shown that the human brain encodes objects according to higher-order dimensions such as their similarity to humans. However, much of our understanding of the neural basis of object recognition is primarily derived from adult studies, despite the fact that children interact with the world in a distinctly different way. For example, preschool-age children tend to attribute characteristics of animate things, like thinking and feeling, to non-living things like toys. Therefore, to investigate how objects are represented in the developing brain, we recorded

electroencephalography (EEG) in children aged four to five-and-a-half years old while they viewed rapid streams of images. Images depicted ordinary objects, such as animals, plants, and tools, as well as more ambiguous categories including robots or animal-shaped toys. By applying multi-variate pattern analysis to EEG, we investigated the neural dynamics of object processing in children. We examined the time course of categorical representations like animacy, as well as dimensions such as 'humanness'. Our findings suggest that object representations in preschool-aged children are similar to adults, but with some delay in the processing of higher-order categories and dimensions. Additionally, our study demonstrates that rapid image streams are an effective way to optimise neuroimaging data collection in children and populations with limited attention spans.

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Talk session 13. Eye Movements

Eye contact avoidance in crowds: A large wearable eye-tracking study.

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Human crowds present an interesting case for the study of visual behavior. Navigating human crowds requires locomotion while avoiding both fixed and moving obstacles. We investigated the flexibility of human gaze allocation in crowds, specifically whether humans are able to avoid eye contact. At a science festival, we fitted 62 participants with a wearable eye tracker and instructed them to walk a route. Half of the participants were additionally instructed to avoid eye contact. We report that humans can flexibly allocate their gaze while navigating crowds and avoid eye contact primarily by orienting their head and eyes towards the floor, not by orienting only their eyes downward with respect to the head. We discuss the implications for crowd navigation and gaze behavior in social contexts. In addition, we highlight a number of problems with regard to eye-tracking data quality, control of the environment, and participant adherence to instruction that are important for wearable eye-tracking studies in unconstrained environments. We stress that methodological innovation and scientific progress are strongly interrelated.

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Investigating spatial navigation using a graph theoretical analysis of eye tracking data recorded in virtual reality

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To investigate visual attention during spatial navigation, recent technical advances facilitate to conduct eye tracking environments in immersive virtual reality environments. However, eye tracking data recorded in 3D environments with freedom of movement require new analysis approaches. Therefore, we propose a new method to quantify characteristics of visual behavior by applying graph-theoretical measures to eye tracking data.

We first apply the new analysis approach to eye tracking data of 20 participants recorded while exploring a virtual city and subsequently conduct the same analysis with data of 26 other participants who explored a different virtual city. In both experiments, we pre-process the data and define "gaze" events, from which we created gaze graphs. On these, we applied graph-theoretical measures to reveal the underlying structure of visual attention.

To investigate the importance of houses in the city, we apply the node degree centrality measure. Our results revealed that 10 houses in the first city and 7 houses in the second city have a node degree consistently exceeding a two-sigma distance from the mean node degree of all other houses. In both experiments all gaze graphs showed a clear hierarchical structure, thus supporting the importance of these houses. As these outstanding houses fulfilled several characteristics of landmarks, we named them "gaze-graph-defined landmarks".

Overall, our findings provide new experimental evidence on visual attention during spatial navigation, which we were able to replicate in a second experiment. Moreover, our proposed method establishes a new approach to analyze eye tracking data recorded in virtual reality.

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Continuous visual tracking performance is strongly influenced by stimulus contrast, type of pursuit, and age

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Continuous stimulus tracking could potentially be used as an intuitive and fast alternative to standard automated perimetry (SAP). However, unlike conventional static SAP, stimulus tracking is a dynamic task and it is therefore not a priori clear what stimulus contrasts should be used for visual field assessment. Additionally, it is unclear how age and type of pursuit affect tracking performance. The purpose of this study was to determine these effects in healthy participants.

We evaluated tracking performance (expressed as the cosine similarity between eye and stimulus movement) in younger and older healthy participants who continuously tracked a semi-randomly moving dot that moved continuously (smooth pursuit) or made occasional jumps (saccadic pursuit) at five contrast levels (5%-80%; 0.3 log steps). Additionally, we compared tracking performance to foveal and peripheral contrast thresholds, as assessed with static perimetry.

Tracking performance of both younger and older participants improved with increasing contrast and was better in smooth pursuit than in saccadic pursuit. The effect of contrast was shifted for older participants: older participants' detection thresholds were about twice as high as the younger participants. Static peripheral contrast thresholds correlated strongly with detection thresholds for saccadic pursuit, but foveal thresholds were not significantly correlated with detection thresholds for smooth pursuit.

Overall, we show that continuous stimulus tracking is robustly affected by stimulus and participant characteristics and that tracking performance relates to static perimetry outcomes. This knowledge can be applied towards an optimized stimulus presentation protocol for visual field assessment based on continuous stimulus tracking.

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A bias in transsaccadic perception of spatial frequency changes

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Visual processing differs between the peripheral and foveal visual field. These differences are especially challenging for transsaccadic perception where an object is seen in the periphery before it is foveated by a saccade. A previous study reported that transsaccadic shape-change perception is biased due to visual field differences. Here, we asked whether similar asymmetries occur in other visual features and how well the differences in appearance between the peripheral and foveal visual field could explain them.

We investigated the perception of spatial-frequency (SF) changes across saccades. The SF of Gabor stimuli either increased or decreased during a saccade, in a range of 0.84 to 4.76 cpd. In a two-alternative forced choice task (Experiment 1), participants showed a bias for frequency-increase reports. Interestingly, a 200-ms postsaccadic blank improved the precision of the responses, but left the bias unaffected. In Experiment 2, participants had to estimate SF of stimuli in the periphery and the fovea separately. There were no differences in appearance between the fovea and the periphery. In a criterion-free transsaccadic change detection task (Experiment 3), participants showed lower thresholds when SF increased than when it decreased, indicating that the bias in Experiment 1 was not merely a response bias. Lastly, in Experiment 4, participants were asked to discriminate SF of the stimuli presented only presaccadically. Thresholds in the presaccadic discrimination task were lower compared to thresholds in the change detection task, suggesting that transsaccadic change detection is impaired by masking or overwriting of the presaccadic stimulus from the postsaccadic stimulus.

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Separate mechanisms for saccadic contrast and motion suppression

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Every time we perform a saccade, the visual scene sweeps with high velocity motion across the retina. Yet, we remain undisturbed by intrasaccadic motion stimulation. The absence of intra-saccadic motion perception might be caused by a

transient reduction of visual sensitivity at the time of saccade initiation, so-called saccadic suppression. Saccade suppression occurs for contrast, displacement and motion stimuli. Saccade suppression of displacements has been shown to be context sensitive such that it inhibits the intrasaccadic sensation only when it expects stimulation. After performing saccades in sessions without intrasaccadic stimulation, saccade suppression magnitude is drastically decreased. If contrast suppression is the reason for the absence of the intrasaccadic motion sensation, it should be similarly modulated by context. To this end, we projected stimuli on a homogeneously white wall such that we could establish a ganzfeld-like environment that, depending on the experimental session, did or did not contain any visible contrast stimuli. We first successfully replicated the context sensitivity of saccade suppression of displacements. Then, we tested context-sensitivity of contrast suppression by asking subjects to perform several saccades either across the uniform white wall or across a background consisting of a sinusoidal grating. In contrast to intra-saccadic context sensitivity for displacement suppression, we did not find context sensitivity for suppression of contrast. These results suggest that saccadic contrast and motion suppression rely on separate mechanisms.

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Auditory contributions to visually-guided eye and hand movements

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Visual information is crucial for motion prediction and online control of interceptive actions. In natural situations, such as in baseball hitting, the environment often offers additional sensory information such as sounds emanating from bat-ball contact. Typically, we associate louder sounds with harder hits and higher ball velocities. In this study, we tested whether humans integrate auditory cues with visual motion signals to visually track and intercept moving objects. Participants (n = 16) viewed the first 100 or 300 ms of a simulated fly ball (black moving dot). Ball launch was accompanied by a batting sound of varying intensities. Participants were asked to track the ball with their eyes and to intercept it at a predicted location with their right index finger. Results revealed a significant effect of sound intensity on hand and eye positions at the moment of interception. The louder the sound, the faster participants estimated the target to move, resulting in overshooting the target. Importantly, this was only found for the short presentation time (100 ms), indicating that auditory cues were mostly used under visual uncertainty. Eye position over time shows that the sound effect emerged approximately 250 ms before interception. Overall, the results indicate that participants integrate auditory and visual cues for motion prediction and interceptive actions, especially when visual information is not reliable.

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Poster session 10. Object Perception

Analyses of the neural population dynamics during human object vision reveal two types of representational echoes that reverberate across the visual system.

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The human visual system enables us to recognize objects in our visual environment. For this, it relies on bottom-up, as well as intricate lateral and feedback connections that dynamically alter its neural population responses over time. Here we explore such dynamics while participants view natural objects in the MEG. We use time-resolved representational similarity analysis (RSA) on source-reconstructed regions across the whole brain and compute cross-temporal representational similarities. This enables us to investigate how the neural geometries change as they unfold in time. We observe two distinct oscillatory patterns that are prevalent across the visual hierarchy. First, we observe representational dynamics that repeat at an alpha rhythm (approx. 10Hz), reminiscent of echoes. These are in line with stimulus-unrelated travelling alpha waves across the cortex and indicate alpha's ongoing effects on cortical information processing in stimulus-evoked responses. Second, when excluding non-stimulus locked neural dynamics using cross-validation techniques, we observe repetitive representational patterns in the alpha and beta band (approx. 7-30 Hz) in which visual responses observed during stimulus presentation reverberate throughout the system. These findings illustrate two modes with which recurrent connectivity can impact ongoing visual computations. Once via ongoing oscillatory responses that add to the stimulus-related computations.

Second via stimulus-locked representational echoes that are in line with a system that repetitively falls back to stimulus-related information, long after the bottom-up signals via stimulus input have disappeared.

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Task-independent allocentric representation of symmetry using polygons

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Visual symmetry generates an ERP component called Sustained Posterior Negativity (SPN). EEG studies have shown that the brain response to symmetry is automatic, and not altered by the participants' task. Moreover, this network can overcome visual distortions that affect regularity (i. e., perspective projections, dynamic integration of parts), and achieve a representation of object's symmetry. This ERP study ads to this literature by investigating object-level (allocentric) symmetry representations. A previous study has shown that these allocentric representations are only achieved when symmetry is task relevant (Makin et al., 2015). However, it is possible that some stimulus types facilitate allocentric object representations and aid 3D representation of the scene. To test this, we compared SPN responses to symmetrical configuration of gabors and solid polygonal shapes, either in a frontoparallel or slanted plane. One group performed a colour discrimination task, while another performed a regularity discrimination task. We observed an SPN response in all four conditions, even when participants were discriminating luminance of gabors that had a perspective distortion. In all conditions the SPN was larger (i.e., more negative) for the frontoparallel stimuli. This suggests that conditions for view invariance are more subtle than suggested by Makin et al. (2015). We conclude that some level of allocentric representation occurs in all tasks and with different stimuli, however, there is also no case where frontoparallel and perspective representations produce an SPN of the same magnitude. Future work will examine SPN magnitude in rich scenes with different cues to facilitate automatic allocentric representations.

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Why there are no mind-independent objects

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An implicit or explicit assumption in most vision research is that there exist objects in the external world, and that we typically perceive them as they are. Illusions and other misperceptions are rare failures of veridical perception. Philosophers have questioned the existence of objects for millennia. For example, Bishop Berkeley proposed that objects disappear when we close our eyes - in other words, he suggested that objects are mind-dependent. Here I show that, given the assumptions and commonly acknowledged results of vision research, there are indeed no ordinary objects. Objects are mind-dependent interpretations of the particles of physics, which, contrary to objects, are mind-independent. Objects are not the input but the output of visual processing. The primary argument is that vision is a non-injective mapping from the large space of physical states into the much smaller set of visual representation. For this reason, there can exist many such mappings, each making up a distinct visual system. Hence, one implication is that different observers may perceive the world quite differently. With a series of experimental findings, I will show that this is indeed the case. For example in spatial vision, different paradigms, such a visual, vernier, and bisection acuity, correlate very little with each other. The same is true for spatial illusions. I will argue that illusions are not misperceptions but reflect individual perception, leaving no space for the existence of objects.

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What kinds of THINGS are SSVEPs (not) measuring?

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Steady-state visual-evoked potentials (SSVEPs) are periodic neural responses where response frequency content is related to the frequency of stimulation. While SSVEPs are increasingly used to gauge high-level visual processing, it remains unclear exactly what information they carry. We used stimuli from THINGS, a large, curated image set, to 1) measure SSVEP reliability, and 2) compare SSVEP to object similarity. On each trial, participants performed a task at

fixation while image pairs were shown. One image ("standard") was presented at a frequency of 6 Hz while the other ("oddball") was shown at 1.2 Hz (every fifth image). We then estimated power at 6 Hz for both image types and at 1.2 Hz for the oddball. Reliability for base frequency power over occipital electrodes was excellent for same standard-oddball combinations, but poor over other electrodes. While a standard image A and an oddball image B evoked consistently high or low responses at the base frequency, their evoked responses at the oddball frequency were quite inconsistent. In accordance with this low reliability, oddball frequency power for a stimulus pair was not correlated with any measures of their similarity, while base frequency power carried some information about low-level similarity of the images (as estimated by pixelwise similarity and shallow CNN layer activations) but not high-level similarity (as estimated by deep CNN layer activations and behavioral similarity judgments). Against our expectations, SSVEP oddball frequency power may not carry much information about the similarity of standard and oddball, but mainly reflects that they are different.

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The role of action-related properties in shaping the object space in the biological and artificial brain

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Deep convolutional neural networks (DCNNs) have become the state-of-the-art models for the human brain by showing partial success in capturing the visual cortex object space. These models are trained in object recognition, thus assuming that the ultimate goal of the ventral pathway is to build an object space that supports object perception. However, accumulating evidence supports the idea that its object space reflects behaviourally-relevant dimensions beyond those necessary for object recognition; for instance, the overlap between hands and tools cannot be explained by visual (e.g., shape) or semantic (e.g., animacy) features specific to each object category, but by the action-related properties common to both. Can DCNNs capture these other important dimensions? To answer this question, we analyzed an fMRI dataset in which participants were presented with three animate (whole-bodies, hands, and faces) and three inanimate (tools, manipulable objects and non-manipulable objects) categories. For brain and DCNNs data, we extracted two indices that reflect behavioural-relevant dimensions over and above object category: the graspability index, reflecting the similarity between body-parts and all graspable objects, and the action index, reflecting the similarity between body-parts and action-related objects exclusively. Our results show that in visual cortex, the object space for body parts and objects reflects behaviourally-relevant dimensions. These effects could not be replicated by DCNNs. These results confirm that the action-related properties are an important dimension driving the object space in visual cortex and highlight the need for more ecological tasks to improve the correspondence between the brain and artificial neural models.

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Characterizing natural image processing in dorsal and ventral areas using fMRI: A Pilot Study

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According to the two-stream hypothesis in vision, the ventral pathway primarily encodes object identity, and the dorsal pathway encodes object features that are key for preparing action (e.g., position, size, distance). The ability to estimate the number of items in a collection has also been linked to parietal regions in the human brain. While we have evidence that object identity and number are coded in these two distinct cerebral pathways starting from three-month-old babies processing artificial and simplified stimuli, we still miss evidence of the segregated role of the two pathways in processing complex, rich natural images. Here we measured brain activity using functional magnetic resonance imaging (fMRI) while adult subjects performed two tasks: a category task, where they categorize complex natural scenes on the basis of the presence of either people or cars, and a number task, where they categorize the same scenes based on the number of objects (2 vs. 4). Category-selective and number-selective visual regions were identified using functional localizers using simplified images. Multivoxel response patterns in the category and number tasks were correlated with response patterns evoked by category-selective and number-selective localizer scans, respectively. A preliminary region-of-interest-based and surface-based searchlight results showed that activity patterns to the scenes containing people or cars and two or four objects were correlated with activity patterns to the isolated pictures of people or cars from the category localizer in the object-selective cortex (OSC) and two or four circles from the number localizer in the parietal regions, respectively.

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Electrophysiological correlates of familiar size.

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Familiar size, the stored knowledge about object size, is a powerful depth cue that allows our brain to infer how far away an object should be to be consistent with its known size. For example, a mouse and an elephant can have the same retinal image size only if their relative distance is just right: the mouse must be near and the elephant far away from the observer. Previous research has shown that familiar size is particularly effective under restricted viewing conditions, where the availability of depth cues is reduced. Here, we recorded ERPs to examine the temporal dynamics of familiar size under natural (lights on, binocular vision) and reduced (dark room, reduction tunnel and monocular pinhole) viewing conditions. Participants were presented with pictures of familiar objects of fixed retinal size (small: x1, medium: 1/10, big: 1/100 the real size) as well as their phase-scrambled versions. Stimuli were matched in terms of luminance and aspect ratio. Participants were asked to maintain fixation and perform a detection task, while EEG was recorded from 64 scalp electrodes. We focused on P1, the first positive component peaking around 100 ms after stimulus onset, which originates from extrastriate visual areas. We found that P1 amplitude was greater in response to familiar smaller than bigger objects, regardless of viewing condition. A similar effect was observed, albeit to a lesser extent, when scrambled pictures were presented. Our findings demonstrate that both familiar size and low-level image properties can modulate the early stages of visual processing.

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Analyzing and Increasing the Similarity of Humans and Deep Convolutional Neural Networks in Object Recognition

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Deep convolutional neural networks (DCNNs) and the human ventral visual pathway share vast architectural and functional similarities in core object recognition. Recent insights have demonstrated that both hierarchical cascades can be compared in terms of behavior and underlying activation. However, current developments in computer vision decrease this similarity in state-of-the-art models. Therefore, to obtain useful, brain-like models for neuroscientific research, we aimed to assess and consequently increase their accordance throughout architectural and data-driven approaches. In a first proof-of-concept study, we demonstrate a comparison of human observers and three feedforward DCNNs with eye tracking and an attribution technique called GradCAM. The results revealed fundamentally different resolutions in measurements that need to be considered and provide further evidence that a biologically motivated modification of receptive field sizes increases the human-likeness of the model. In a second follow-up study, we used eye tracking data to directly manipulate training images and thereby draw the attention of the model to features that are important to human observers. Additionally, we refine this comparison by considering and exploring the time lag between cortical feedforward and feedback processing as well as consequently performed eye movements. With these approaches, we try to open new perspectives at the intersection of biological and computer vision research.

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The Impact of Anchor Objects on Scene Affordance Understanding

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Every day, we constantly interact with the objects around us. Studies suggest a high importance of anchor objects during visual search and scene understanding (Võ, 2021), but the impact of anchor objects on the perceived functionality of a scene remains unexplored. In the current study, we investigated the influence of different action related and unrelated anchors on the understanding of scene affordances, i.e., the action possibilities in a scene. We investigated this by presenting an indoor scene in which either an action-related anchor object (a stove and the action cooking), an action-unrelated anchor (a fridge and the action cooking) or a random object was masked. Participants then performed a lexical decision task of non-words vs. action-words, the latter being either consistent with the scene (a kitchen and the action cooking) or inconsistent (a bathroom and the action cooking). Reaction times were faster when words were semantically consistent than when they were inconsistent. Within the semantically consistent condition, participants' reaction times were fastest when random objects were masked and significantly slower when anchors were masked, regardless of whether they were related to the presented action or not. The findings suggest that the presence of anchors in a scene impacts the perception of a scene's affordance to such a degree that it modulates lexical access to action words. We conclude that anchor objects do not only hold predictions about the presence of other objects but also shape the way we perceive and understand action potentials in scenes.

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Poster session 11. Perceptual Organisation

A Neurodynamic Model of the Role of Accentuation in Figure-ground Segregation

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The accentuation had been recently proposed as a general principle of figure-ground assignment that can override classical Gestalt principles such as size, closure, or convexity. Here, we developed a neurodynamic model to account for properties of accentuation and its relation to other figural cues. The model consists of four processing stages, each involving retinotopic maps: 1) a set of feature maps that compute bottom-up saliency; 2) a network for visual segmentation that employs inhibitory connections to segregate surfaces into distinct layers; 3) a feature-based winner-take-all network that selects most salient locations in the map and 4) a network that enables spreading of enhanced neural activity from the most salient locations to all connected locations. Proposed networks form a feedback loop that guides surface segregation. Computer simulations showed that the model correctly predicts appearance in many of the stimulus configurations designed to test the effectiveness of accentuation. These include examples showing that accentuation biases square-diamond illusion, generates reversals of tessellations, and dominates over size, closure, convexity, and similarity. The model suggests that the accentuation is a consequence of surface segregation that is automatically triggered by the most salient locations in the image. The proposed model also accounts for similarity-based groupings and the pointing illusion and its variants.

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Visual Perception of Bouncing and Jumping

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We systematically explored the degree of consistency between the physical and the perceptual laws of the events of bouncing and jumping. Several parameters of the animation were manipulated across four experiments. Participants were presented with animations showing a small disk moving vertically back and forth repeatedly along the vertical axis of the screen, and had to indicate if the display showed the bounce of a physical inanimate object, the animated motion of a living creature, or an undefined motion. The results revealed that uniform acceleration tended to enhance visual impressions of a physical bounce, although this effect was more evident in the case of one bouncing cycle than in the case of three bouncing cycles, and for values of acceleration much smaller than 9.81 m/s2; moreover, physical bounce impressions were more likely for values of C (coefficient of restitution) < 1, and by delays at the impact in the range 0-30 ms. The animated jump impressions were more likely for values of C > 1 and by delays between 90-150 ms. Interestingly, neither physical bounces nor animated jumps were affected by the presence or the absence of a bouncing surface. Overall, the results indicate that visual impressions of physical bounce and animated jump strongly depend on kinematics, can be visually perceived in a relatively direct and automatic manner, and are largely independent of the corresponding physical laws, consistently with the Gestalt-theoretic account of event perception.

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Effect of Interocular Grouping Demands on Binocular Rivalry

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Binocular rivalry is the phenomenon that when two incompatible images are simultaneously presented, one to each eye, the two images compete with each other to be the dominant percept. Remarkably, binocular rivalry accommodates interocular grouping so that if portions of two globally coherent images are shown to each eye, subjects still perceive the global pattern far more often than would be expected by chance. In this study, we recorded subject's perceptual reports (N = 48) while viewing classic rivalry with orthogonal gratings (red in one eye and green in the other). This was compared to conditions with increasing grouping demands; stimuli were divided into 2, 4 or 6 patches with alternating patches shown to each eye. With classic BR, subjects perceived one of the two coherent images ~75% of the time, and reported a mixed (piecemeal) percept 25% of the time. With 2-patch stimuli, dominance of either global percept vs. a mixed percept were each seen ~50% of the time. For 4 or 6 patches, the global dominance time is reduced only modestly and saturates such that dominance, or mixed percepts were always seen ~40% and 60% of the time, respectively. Mean dominance durations: 1-2 sec throughout. Mean mixed durations: 0.5 -3 seconds. Data suggests that grouping across the vertical meridian is slightly more robust than across horizontal meridian, and future plans include analysis

of related MEG data. Current results show that rivalry remains stable with increasing grouping demands, but modestly reduces the amount of time dominance occurs.

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A model of 3D surface ownership assignment

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It has become clear that the mammalian visual system has the ability to assign border-ownership for 2D object images. On the other hand, since the 3D world is usually viewed binocularly, borders of objects correspond 3D surfaces instead of 2D contours. Therefore, the visual system needs to determine the side of object region at each local surface area. Alike 2D cases, 3D objects have both convex and concave parts, and the proportion of convex parts always exceed concave parts. With such property in mind, we constructed a neural network model assigning ownership of 3D surfaces by extending the previous 2D border-ownership model proposed by one of us.

Dimension of the input space is 3D assuming the stage after binocular correspondence problem is solved. At each surface point, a pair of surface ownership neurons are prepared and connected mutually with the same ownership polarity within a local spatial range, contributing to smooth the responses. In addition, mutual inhibition is equipped between each pair of antagonistic ownership neurons. Absolute values of curvature are given as initial value of neurons for inner side of the local ridges of surface, irrespective of global inside/outside. After iterative calculation, positive responses remain only on the neurons corresponding global interior of the surface. We tested the model on a computer. For 3D objects with random convex and concave structures, the model detected successfully global inner side.

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Spatio-temporal anisotropies in summary statistics

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Human observers can extract global summary statistics, such as the average size or orientation of a set, swiftly and with high precision. In previous work, we found that summary statistics are non-uniformly weighted in space and biased towards the properties of individual elements near the center-left region of the visual field. The center-left bias occurred in retinotopic coordinates and was independent of the stimulus duration and level of uncertainty. However, the source of these spatial anisotropies and whether the center and left-side bias reflect the same mechanism remains unclear. Here we used a novel paradigm in which information about the ensemble needs to be integrated over space and time. Observers were asked to reproduce the perceived average orientation of an ensemble of tilted Gabor stimuli that appeared around the fovea with random temporal jitters. Using a modified spatial weighted average model, we estimated the weights of each Gabor in perceptual averaging, depending on its position in time and space. Our preliminary results indicate that the bias toward the center rises quickly and reaches a steady level, likely reflecting the preferred location for evidence accumulation over time. Conversely, the left-side bias presents more transient dynamics, which may reflect attentional biases.

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Perception of node-link diagrams: the effect of layout on the perception of graph properties

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Node-link diagrams are commonly used to visually represent networks of entities (nodes) and their relationships (links). They are widely used to display and communicate linked data, such as social networks, tube maps, wireless sensor networks, or even EEG data. The way we draw such networks (layout) affects the complexity of various computation problems on networks. In this empirical study, we examine how different layouts affect the human perception of four different properties of 16-node networks. We compare a simple grid layout to the planar and force-directed layouts, which are some of the most well-established layout algorithms for drawing networks. We also introduce an alternative 'improved' grid layout, which optimizes the drawing in terms of specific aesthetics, such as the number of line crossings. We use a Yes-No design, where participants have to decide whether a graph has a given property or not, and we perform a signal detection analysis. The results show that the layout is crucial for our perception of some of the network's basic properties, such as connectedness and treeness. However, the chosen layout doesn't seem to significantly affect sensitivity when detecting the density of the network, or when people detect a property that consists of a combination of two features at a time. The layout, as well as the specific aesthetics of the stimuli, were also found to affect the detection bias toward different directions, for some of

the properties. The study provides both qualitative, as well as quantitative results about the specific strategies used.

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Poster session 12. Perceptual Decision Making

Effects of expected dynamic material properties on perceptual decision making

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We hold expectations about material dynamics, and can implicitly predict objects' future states, e.g. a wine glass falling down will break when it hits the ground. How these expectations affect perceptual decisions, however, has not been systematically studied previously. To seek an answer to this question we conducted a behavioral experiment using animations of various familiar objects (e.g. key, wine glass, etc.) freely falling and hitting the ground. During a training session participants first built expectations about the dynamic properties of those objects. Half of the participants (N=28) built expectations consistent with our daily lives (e.g. a key bounces rigidly), whereas the other half learned an anomalous behavior (e.g. a key wobbles). In the experimental sessions participants' learned expectations were violated in 20% of the trials. In both training and experimental sessions, participants' task was to report whether the objects broke or not upon hitting the ground. Note, that a specific object always remained intact or broke, only the manner with which it did so differed. For example, a key could wobble or remain rigid, but it never broke. We found that participants' reaction times were longer when expectations were violated even when those expectations were anomalous and learned during the training session. Furthermore, we found an interplay between long-term and short-term expectations, which could potentially be predicted by a Bayesian updating model. Overall, our results show that expectations about dynamic material properties can have an impact on low-level perceptual decision-making.

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Reproduction, but not confidence, can dissociate conscious perception from non-perceptual bias

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A central problem in consciousness research is how to operationalize consciousness. Subjective conscious experience is often gauged using a decision measure combined with a subjective scale or a confidence scale. However, both decision and subjective behavioral responses may not accurately reflect an observer's conscious experience because of non-perceptual bias (cognitive and/or response criterion shifts). In previous experiments, we have introduced a new measure of consciousness: 'controlled reproduction', which we have shown to be free from such non-perceptual biases. Here we present two experiments in which we compare reproduction to two popular methods of confidence measurement: concurrent and delayed confidence. In both experiments, we compare reproduction to confidence measurement under three bias manipulations: the Müller-Lyer illusion, a pay-off scheme, and an asymmetrical base-rate. All three bias manipulations were shown to successfully shift the point of subjective equality. Importantly though, we confirm previous findings that only the Müller-Lyer results in a shift in reproduction (perceptual), while pay-off and asymmetrical base-rate do not (non-perceptual). Next, we reasoned that if confidence selectively reflects conscious perception, it should only shift the point of peak uncertainty (lowest confidence reported) during perceptual manipulations, but not during non-perceptual manipulations. To our surprise however, we show that bias 'leaks' into confidence under all three manipulations, and that it does so both during concurrent and during delayed confidence measurement. These results show that confidence is not free from non-perceptual influences on bias.

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Sub-second dynamics of precision and confidence following voluntary shifts of spatial attention

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Orienting attention voluntarily has recently been linked to a transient cost for metacognition (i.e., how well subjective

confidence reflects objective precision). Here, we used a dual-task paradigm to probe the fine-grained temporal effects of voluntary, spatial attention on precision and confidence. The paradigm involved the discrimination of the orientation of a target Gabor displayed together with a distractor Gabor, presented after a precue (70% valid). At different delays after Gabors offset, two oriented landolt-Cs were briefly presented at the same two locations. Participants (N=14, ~5K trials/participant) both discriminated the orientation of the target Gabor (first task), and reproduced the orientation of each landolt-C (second task) using the mouse cursor. The second task was used to probe attentional state at various moments after initial deployment, and was followed by a confidence judgement on reproduction precision. We observed that attention induced a spatial distribution of resources which outlasted the first task requirement, strongly swaying the local encoding of probes presented up to half a second after the initial target. Such a trailing effect in resources allocation was observed for both orientation and late reorientation of attention (following an invalid cue), attentional disengagement being seemingly subject to relative inertia. While confidence judgments were sensitive to the reproduction precision on a given trial, they were also favoring the attentional locus independently of actual performance. Importantly, metacognitive ability was dampened following the late reorienting of attention, suggesting an intricate relation between metacognition and the executive control of visuospatial attention.

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Abstract neural choice signals in the presence of consistent choice-action associations

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Humans can make abstract decisions that are not linked to actions. However, in many previous experiments perceptual choices were associated with specific actions, leading to a framework of choices as action selection. This interpretation has been called into question by studies seeking to disentangle choice- and action-related neural activity. For example, using MEG we recently demonstrated abstract neuronal choice representations when participants reported the presence or absence of coherent visual motion regardless of whether participants knew the mapping between choice and action in advance. Here, we tested whether an abstract choice representation is also present in a symmetrical choice task (up vs. down motion discrimination) and if the mapping of choice to action is always known in advance. Participants performed motion discrimination whilst we recorded MEG signals. Using multivariate decoding techniques, we found neural activity that reflected abstract perceptual choices, i.e. choices independent of the presented stimulus and behavioural response. Our results suggest that an abstract choice stage may play an important role across different decision types and even if choices are consistently linked to actions.

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Serial dependence by mental imagery

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In serial dependence (SD), perceptual decisions deviate toward the recent past: the orientation of a visual stimulus is reported as more similar to the orientation of previous stimuli than it really is. At present, this phenomenon has always been reported in the presence of physical stimuli. As a result, SD has been mostly interpreted as reflecting a mechanism that stabilises perception by combining prior and present visual input. Here we demonstrate that physical stimuli are not a prerequisite and SD can occur in the total absence of visual input. In two experiments, we asked participants to imagine and reproduce an orientation cued by a numeric digit and then to reproduce the orientation of a real Gabor patch. In Experiment 1, participants reproduced the imaginary and then the physical orientation in each trial. In Experiment 2, we additionally presented an irrelevant physical Gabor that participants had to ignore while imagining the cued orientation. Mental imagery in the lack of physical visual input led to strong SD: only the imagined orientation biased the report of a physical one, but not the other way around. Even more, the irrelevant stimulus presented at the time of the imagined orientation caused a repulsive bias in the following decision. Hence, SD occurs in the pure absence of visual input, suggesting that the integration of prior and present information resides at the level of abstract representations rather than low-level physical features.

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Visual serial dependence is an assimilative effect between responses not stimuli

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Visual perception is often influenced by the recent past. Serial dependence is a misperception which exemplifies this; assessment of the current stimulus appears to be

blended with the previous stimulus. This has been widely demonstrated in orientation perception where observers' orientation judgements are attracted towards the orientation presented immediately prior to the current stimulus.

There is some debate over what drives this assimilative effect. It could be that observer perception itself is altered by recent stimulus history. Alternatively, the decisions observers make might just be attracted towards their previous choice, a post-perceptual process which could be misinterpreted as perceptual blending. We aimed to test this experimentally in a task involving orientation judgements. A clear assimilative effect was evident between trials when participants (n=15) reproduced stimuli with randomly selected orientations. In a separate set of test trials, the orientation value of the currently displayed stimulus fell directly between the previous stimulus value and its associated response value. This created a situation where previous stimulus and response were in opposing directions from the current stimulus. In this case we found that current responses were biased away from the previous stimulus whilst being attracted towards the previous response. These results support a narrative in which serial dependence is determined by the previous decision made about a stimulus rather than the previous stimulus itself.

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Central EEG components P2 and P4 are sensitive to differentiating between bistable and unambiguous kinetic-depth effect displays

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The main goal of the visual system is to generate unambiguous percepts to allow decisive action planning. We were interested in EEG components being sensitive to the process before reaching this, at least temporary, stable percept. Specifically, we compared bistable and unambiguous (strongly biased) stimuli as in EEG recordings they produce the difference in amplitudes for P2 and P4 components particularly prominent for central electrodes. The aim of the study was to replicate the earlier work using the Necker cube (NC) stimulus and extended it to an additional class of stimuli: kinetic-depth effect (KDE). Both displays were shown intermittently (800 ms on, 33 ms off) with participants responding on perceptual changes for fully ambiguous and full unambiguous replay sequences. We used a 32 electrode Brain Vision setup with data analysis performed via MNE Python toolbox. The results replicated earlier work and were qualitatively and quantitatively similar for NC and KDE stimuli with lower amplitude for both P2 and P4 components and higher latency for a behavioral response for ambiguous stimuli during perceptual switches. Thus, the P2/P4 components seem to be reliable indicators for detecting stimulus ambiguity when it remains constant throughout a block.

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Poster session 13. Attention - II

Exploring the role of curiosity in attention capture

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Most cognitive psychological studies assume that participants in a lab-based task maintain only one goal and any behaviour that is not in alignment with the instructions is considered to indicate a failure of top-down control. People, however, can be motivated by factors other than task-related instructions, such as curiosity. We manipulated curiosity through stimulus uncertainty in a version of the Posner cueing paradigm. Participants ($n = 40$) were presented with an abrupt-onset cue followed by a single letter target (E or H). The letter target was followed by either a mask at the target location (low uncertainty/curiosity) or masks at all four locations in the display (high uncertainty/curiosity). The difference in errors between invalid and valid conditions was greater ($p = 0.014$) for the high uncertainty condition compared to the low uncertainty condition. The same pattern was seen for d primes. The influence of the cue was greater in the high uncertainty condition possibly due to enhanced curiosity. To distinguish if this result was indeed due to an increase in uncertainty and not the difficulty, trials in which the difficulty was increased (by reducing the target contrast) while keeping uncertainty low (single mask) were included. Here, the cueing effect was equivalent to the low uncertainty (easy) condition supporting our conclusions. A second experiment is underway to examine if the results can be attributed to curiosity associated with the target display or a general state of curiosity triggered by the four masks.

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Feeling in control of reward boosts the reward cue attentional salience

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Reward predicting stimuli summon attention. However, reward attainment can be experienced with different types of control (internal vs external). In the present study, we investigated whether the control style in reward gain affects the attentional salience of reward cues. In Experiment 1, participants took part in a wheel-of-fortune like game to earn reward points, where they were asked to stop the ball on the wheel sectors delivering the highest points. However, depending on the color of the wheel, the ball landing position was under participants' control (internal locus-of-control), or determined autonomously by the computer (external locus-of-control). After this training, participants developed an attentional bias in favor of stimuli with the same color of the wheel associated with an internal locus-of-control in reward gain. The same procedure was adopted in Experiment 2, except that participants sought to avoid points loss, with the results showing that the type of control per se is not sufficient to confer attentional salience to outcome-associated stimuli. Experiment 3 replicated the results of Experiment 1 while excluding alternative accounts. Our study reveals a novel finding showing that the reward-cue attentional salience is jointly affected by the style of control in reward gain and by reward value.

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Goal-directed attention modulates neural representations of object selectivity - An MEG-fMRI fusion study

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We constantly encounter a continuous flow of information from visual environment. A same stimulus may differ in their relevance based on the task goals. The human brain requires mechanisms to select relevant information for guiding behaviors. Goal-directed attention is thus crucial in object selectivity. Extensive research has demonstrated that representations of visual objects could be identified in the patterns of activity within visual extrastriate areas that could be modulated by the prefrontal and posterior parietal cortices (PFC and PPC). Here we investigated the spatiotemporal profiles of neural representations underlying object selectivity in visual extrastriate regions and determined the source of top-down signals representing goal-directed information. We conducted a multivariate fusion analysis to combine the representational patterns for sensor-level MEG signals with those for voxel-level fMRI responses. Twenty-four participants viewed streams of face and house images in both MEG and fMRI experiments. They attended to faces or houses and responded to pre-defined targets. Our fusion results showed the attentional enhancement on MEG-fMRI representational similarity for face and house selectivity in the category-selective visual areas (fusiform face areas and parahippocampal place areas) and the PPC bilaterally and the left PFC. Importantly, we tested effective connectivity among the category-selective areas, the PPC and the PFC using Granger causality analysis. We found that goal-directed modulation of MEG-fMRI representational similarity in the FFA and PPA was guided by the PFC. Together, this study provides novel evidence for the spatiotemporal properties and neural mechanisms underlying goal-directed modulation of object selectivity in the human brain.

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A dual-process model of visual perspective taking: the role of others' directional features

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People's attention is influenced by what others are looking at. To study this phenomenon, Samson et al (2010) devised the Dot Perspective Paradigm (DPP), in which participants are presented with a scene and a cue directs attention towards some targets. This task shows an interference: participants record slower RTs and more errors when the cue is facing away from the targets. To explain this phenomenon, the mentalizing account emphasizes the social relevance of the cue; whereas the domain-general account focuses on its directional features. We proposed a dual-process model which integrates the two accounts consisting of i) an orienting process, sensitive to directional features – such as the posture - and assessed by RTs; and ii) a decisional process sensitive to social features - such as the viewpoint - and assessed by both RTs and errors (Pesimena & Soranzo, in press). To test this model, we used a modified version of the DPP in which a devil shaped cue had an arrowed shape tail that pointed either to the same or the opposite direction of the face, thus manipulating both directional and social features separately. Results show that the interference persists when the tail is pointed to the same direction of the face, whilst it disappears (only in the RTs) when the tail pointed to the opposite direction. This result is consistent with the dual-process model: the orienting process is affected by the devil's posture and direction of its tail, whilst the decisional process is affected by the devil's viewpoint.

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Independent attentional facilitation of single features accounts for conjunction selection in early visual cortex and in behaviour

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Attentional selection in complex scenes often involves prioritising multiple object properties – feature conjunctions -- at once. Conjunction selection in early visual cortex has been previously described as a result of parallel and independent selection of single constituent features. Here we used behavioural modelling and electroencephalographic recordings to test whether independent selection of single features also explains behavioural performance in conjunction-selection tasks.

Participants observed four concurrently presented spatially overlapped fields of randomly moving red or blue bars oriented horizontally or vertically. On each trial their task was to attend to the cued type of bars in order to detect to brief coherent motion events. Depending on the condition, cues specified either colour of the attended bars, their orientation, or a combination of the two. The strength of attentional selection for both single features and the resulting conjunction was measured in early visual cortex by means of steady-state visual evoked potentials (SSVEPs). Reaction times were analysed using the shifted Wald model, isolating the rate of accumulation of sensory information from decision-related components of the reaction times. The results showed that conjunction selection is brought about by parallel facilitation of its constituent single features, and that this mechanism manifests itself in the SSVEP amplitudes as well as in the reaction time distributions. Further, on the individual level the magnitude of attentional effects in SSVEPs was associated with reaction time gains. We conclude that behavioural performance in a feature-conjunction task is determined by separate attentional facilitation of constituting features in early visual cortex.

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The multidimensional spotlight of attention

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The Spotlight and Zoomlens metaphors of attention have had, and still have, a profound influence on how researchers conceptualise and investigate visual selective attention. Since their development, subsequent research has shown that attentional selection is not just the product of a unitary mechanism for selection of spatial locations but involves the joint operation of largely independent mechanisms that bias processing resources towards relevant information based on simple stimulus features such as colors, orientations, motion, and spatial location. A substantial amount of research has considered these mechanisms individually. However, in more complex situations (e.g. real life) relevant stimuli may not be set apart from other stimuli by a single defining property, but by a specific combination of features. In such cases, effective attentional selection can only be achieved by concurrent selection of multiple features (e.g. feature conjunctions). To understand attention beyond artificial simplistic situations, it is therefore essential to know how attentional selection of different stimulus features is combined. In this talk I will provide a synthesis of findings from a series of EEG experiments on feature-based and spatial attention and integrate them into an extended spotlight metaphor.

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Population receptive field properties in human cortex are altered by precision of visual spatial attention

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Perception is enhanced at spatially attended locations. The attention field model, which summarizes the locus of attention by a Gaussian field, is often used to capture how population receptive fields (pRFs) are influenced by attention. Specifically, previous research demonstrated that pRFs are attracted to the position of the attentional locus. The attention field model predicts that in addition to the position of the attention field, its size also influences pRF properties. This size, i.e. the standard deviation of the Gaussian attention field, corresponds to the precision of spatial attention. Here, we investigate the effect of attentional precision on pRF properties while keeping the attended location constant.

We measured pRFs using ultra-high field MRI while participants performed one of two tasks: a high-precision task at fixation and a task that maximally distributed attention across the entire screen. The standard pRF mapping bar stimulus was used.

Behavioral results showed that participants were able to modulate their spatial distribution of attention and that the difficulty of the two attention conditions was matched. The fMRI time courses revealed structured task-dependent differences. These time-series differences translated into eccentricity-dependent task responses, where foveal responses were stronger to the high-precision task

and vice versa. Furthermore, pRF positions were also altered as a function of the attentional precision of the task, in line with the attention field model.

These results indicate that the precision of the spotlight of attention influences visual representations of space in line with the predictions of the attention field model.

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Pupil size and spatial attention are modulated by sensory processing sensitivity.

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Sensory processing sensitivity is a biologically-determined increased susceptibility to environmental inputs. It includes perceptual sensitivity - being able to notice subtle stimuli and being more easily overwhelmed by intensive stimuli - and affective sensitivity, i.e. sensitivity to the emotional clues. However, the relation between perceptual and emotional sensitivity is still far from clear. The current study aimed to examine the impact of emotional load, visual saliency, and their interaction on the visual attention patterns and psychophysiological reactions among people varying in the sensory processing sensitivity.

We manipulated the visual saliency of the key objects in the emotional images (negative, neutral, positive) to obtain three conditions: saliency increased, decreased, and unchanged. Participants (N = 60) saw 315 pictures in a free-viewing procedure. Participants' sensory processing sensitivity was measured using the Highly Sensitive Person Scale for research purposes.

More visually salient key objects evoked more pronounced pupil constriction and preferentially captured attention, as observed for the initial fixations. Emotional content began to influence attention at the later stages - people longer explored negative objects. Moreover, we observed higher pupil dilation in reaction to negative images.

Importantly, sensory processing sensitivity modulated observed effects. Highly sensitive persons fixated less on the key objects in negative images. They also had more dilated pupils - especially in reaction to salient stimuli - than participants scoring lower on sensory processing sensitivity.

Overall, the results suggest that the emotional component of sensory processing sensitivity shapes attention engagement, while the perceptual component impacts the autonomic reaction.

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Multidimensional discrimination of compound visual stimuli by pigeons after attending dimensions of which they are composed

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Pigeons can categorize a stimulus as a compound image as well as made up of separable dimensions. To discriminate unique multidimensional stimuli it is not always necessary to learn them as compound stimuli. We trained pigeons (Columba livia) on a stagewise go/no-go visual discrimination task. 16 compound stimuli were created from all 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). Starting with 1 S+ and 1 S- that differed in all 4 dimensional values, in later steps, we added one by one S-s stimuli by sorting out all 4 dimensions. When pigeons clearly have selectively attended to each of four dimensions we presented all 16 stimuli. In this last stage pigeons rejected correctly most of S- stimuli at once. Mistakes were associated with similarity to S+ (most pigeons confused S- stimuli shared 3 (some 2) dimensions with S+). Moreover, knowledge of the first learned dimensions of compound stimuli was less reliable than dimensions learned in the later stages. Thus, to discriminate 16 unique multidimensional stimuli it was not necessary to learn all of them as compound stimuli. However, in such approach learned 4 dimensions did not give fully comprehensive information about all unique new compound stimuli presented in the last stage.

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Sustained attention and motivation: dissociable effects of motivation types on the Sustained Attention to Response Task variables.

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Sustained attention is the capacity to maintain a focussed state of mind for an extended period of time. It is well known that motivation facilitates sustained attention which can improve performance on a task. However, there are different types of motivation, which may have different effects on sustained attention. To address this, we investigated the effects of intrinsic and extrinsic motivation on multiple variables related to sustained attention. Participants completed an online 26-minutes

version of the Sustained Attention to Response Task (SART), a fast-paced go/no-go task which requires participants to withhold responses to rare targets. They were informed that they would gain additional compensation dependent on their performance. Critically, to manipulate extrinsic motivation, the "reward" group (N=104) was informed before starting the task whereas the "no-reward" group (N=105) was informed after. Intrinsic motivation was measured with the Dundee Stress State Questionnaire (DSSQ) for both groups. Multilevel modelling showed an effect of extrinsic motivation on attentional lapses, measured by the average reaction times (RT) for the slowest 20% of trials. By comparison, intrinsic motivation correlated with perceptual sensitivity and RT variability. A vigilance decrement, the worsening of performance over time-on-task typically found in the literature of sustained attention, was found regardless of motivation type. Finally, a frequency analysis was used to investigate whether reaction-time oscillations varied between groups, but no significant results were found. The differential effects of intrinsic and extrinsic motivation on different performance variables suggest that there are multiple dissociable mechanisms underlying sustained attention.

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Poster session 14. Social Perception

E-Motion: a database of bodily expression of basic and social emotions

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Our bodily movements carry rich communication information, yet a database is not well established for the development of an intelligent system to decode embedded emotions. The available databases are limited because (1) they usually recruit only a few professional performers (2) in Western countries (Europe/USA) to (3) perform identical scripts or specified actions.

To fill in the gap, we develop a database (E-Motion) by using a motion capture system (Vicon) to record Asian professional actors performing 7 basic emotions (joy, sadness, anger, fear, surprise, disgust, contempt) and 5 social emotions (gratitude, guilt, jealousy, pride, shame. For each emotion, actors use their whole body (with face cover) to perform 3 self-selected scenarios that elicit the target emotion in 3 intensity levels (low, middle, high) within 2-5 seconds. Our protocol includes a broad coverage of real life events eliciting common emotions. Qualitative and quantitative approaches are applied to analyze how specific emotion associates with the motion unit (e.g. flexion and extension of each joint, adduction and abduction, internal and external rotation, combinations of motion elements and their velocities, etc.). A new group of participants are invited to judge what category and intensity they perceive from the extracted biological motions.

Our database (E-Motion) is the first step toward a standard coding system that categorizes bodily emotions based on corporal movement units, and an intelligent system that understands rich non-verbal information.

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National favoritism in face perception - a free-viewing study

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Face perception is an important facet of intergroup research as the face features provide physical and social cues relevant for ingroup and outgroup categorization of others. Previous research suggests that preferential attention to the eyes is characteristic of ingroup face processing. In the poster entitled "National favoritism in face perception - a categorization study" we show an enhanced eye contact for faces perceived as the national ingroup. This study, however, has not established causality between being perceived as ingroup and increased eye contact. Hence, in the current experiment we experimentally manipulated beliefs regarding faces' nationality and examined how it influences attention to the eyes. Polish participants (N = 43) viewed 180 multinational (all White) faces, for which the "Polishness" rating was obtained in the first study. The faces were randomly preceded by a "Polish nationality" or "Foreign nationality" tag. Attention to the eyes depended both on the tag and the appearance of the face. In particular, participants avoided eye contact with faces rated as appearing non-Polish when they were congruently tagged as foreign. However, when the same faces were incongruently tagged as Polish, the participants maintained the same amount of eye contact as with faces of more ingroup appearance. Additionally, we noted a much lower fixation proportions towards the eyes compared to the first study, indicating that attention to the eyes serves social categorization, as the eyes provide relevant information regarding group identity. Overall, the results of both studies suggest a causal relationship between ingroup membership and enhanced eye contact.

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Early impact of task instructions on gaze processing: an EEG study.

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The direction of another person's gaze provides crucial information about their attention and intentions, which is essential for a fast and effective social interaction, especially when eyes make contact. Event-related potential (ERP) measurements provide accurate temporal tracking of neural processes related to gaze perception. While the sensitivity of the N170 ERP component in face processing is mostly recognized, research on the effect of gaze direction on this component has so far been inconsistent. However, differences in task instructions could explain part of these inconsistencies. In this study, we assessed the impact of task instructions on gaze direction sensitivity. Thirty-six participants performed the task, which presented faces with direct or averted gaze and non-face stimuli simultaneously on two hemifields with varying task instructions: i. e., face detection, gender categorization, and gaze discrimination. Behaviorally, we demonstrated faster processing for faces with direct gaze in the detection task and the gaze discrimination task, but not in the gender categorization task. The amplitudes of lateralized-N170, the marker of face encoding, were greater for direct gaze compared to averted gaze, regardless of the task. Critically, global brain activity analyses with two independent measures revealed a short-lived but significant interaction effect around 50-80ms, driven by differences between gaze conditions only in the gaze discrimination task. Our findings show the early impact of task demand on the sensitivity of gaze direction.

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Perception of audiovisual speech synchrony for familiar and unfamiliar ethnic speakers.

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Whether audiovisual inputs are integrated or separately processed depends on the congruency, e.g., temporal synchrony, between them. Some studies have assumed that familiarity with the stimuli influences the integration process. Here, we investigated how familiarity with the speaker's face and voice influences audiovisual temporal binding processing. In the experiment, we presented the audiovisual speech by speakers of familiar and unfamiliar ethnic groups with various A/V onset asynchronies within +/- 800 ms. We asked participants to judge the synchrony of audiovisual stimuli, and then calculated the temporal binding window (TBW) and the point of subjective simultaneity (PSS). The results show that the range of TBW in the familiar condition was comparable to that in the unfamiliar condition. On the other hand, our results showed that the familiarity with the face influenced on PSS. In detail, the participants tend to perceive as simultaneous when visual stimuli led to auditory stimuli by a significantly larger interval in the familiar condition than in the unfamiliar condition. These results are consistent with previous results showing that observers' prior experience (familiarity with spoken language) was involved in the perception of audiovisual speech synchrony.

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Loneliness effects on the own-age memory bias for emotional faces.

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Previous research shows an Own Age Bias in young adults, which has been attributed to the greater contact with, and/or to the greater salience of, others who belong to the same group. Importantly, there is some evidence that when emotional faces are used such effect is eliminated. Considering that the Own Age Bias relies both on social contacts and salience of same-age individuals, the present study investigated whether self-reported loneliness modulates the Own Age Bias for neutral and emotional faces. To this end 235 young individuals completed a loneliness questionnaire and a two-phases task. During the encoding phase, participants were presented 72 faces shown in 3 expressions (neutral, happy, angry). Their task was to categorize the faces as old or young. In the test-phase, participants were presented the 72 faces seen during encoding intermixed with a new set of 72 faces and were instructed to respond whether the face was already seen or novel. Findings showed an Own Age Bias due to greater accuracy in recognising younger than to old seen faces [Young-(Old)], B=0.06, 95% CI [0.03, 0.09], SE=0.01, t (1170)=4.48, pholm <.001). Participants were also more accurate in recognising emotional compared to neutral faces, [Neutral-(Angry, Happy)], (B=0.03, 95% CI [0.00, 0.06], SE=0.01, t(1170)=2.28, p=.023). The interaction term (Age by Emotion) was non-significant (F(2,1170) =2.14, p=.12). Additional analyses showed that, there was a small effect of own-age biases for Novel Happy faces on loneliness scores (B=-4.44, SE=2.04, 95%CI [-8.46, -0.43], t=2.18, p=.03) indicating that stronger own-age biases are associated with less loneliness.

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National favoritism in face perception - a categorization study

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National favoritism, i.e., preferential treatment of own-nationality individuals, manifests itself in economic games, attractiveness rating, and real-life situations, e.g. among sports referees. We hypothesized that national favoritism would be also detected in the face-viewing pattern, as more eye contact with own-nationality faces. Enhanced eye contact with ingroups has been documented in cross-race and minimal groups paradigms. In this study, 33 Polish participants (all White) viewed 300 multinational faces (all White) and rated their appearance on the "Polishness" scale, while their eye movements were recorded. We analyzed the proportion of the first and later fixations directed to the eyes, mouth, and nose. In both initial and later fixations we found a linear trend between the proportion of fixations in the eyes and the "Polishness" rating: the more "Polish" a face was perceived, the more attention to the eyes was directed. No effects of the "Polishness" rating were detected for fixations directed toward the mouth or nose. Additionally, we found an effect of sex of the face: more first fixations were directed to the eyes of women than men. However, the sex of the face did not interact with the "Polishness" rating, proving that these factors independently influenced attention engagement with facial features. This study suggests national favoritism can manifest itself in the form of enhanced eye contact, however, it does not allow to establish a causal relation between them. To this end, we conducted a second experiment, presented in a poster entitled "National favoritism in face perception - a free-viewing study".

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Early Gaze direction processing: insights from ERP decoding

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The current pandemic situation and the use of the masks have shown the importance of eyes in social communication. Distinguishing the direction of another person's eye gaze is extremely important in everyday social interaction, as it provides critical information about people's attention and, therefore, intentions. The temporal dynamics of gaze processing has been investigated using event-related potentials (ERPs) recorded with electroencephalography (EEG). However, how fast our brain distinguishes gaze direction remains unclear. To solve this question, the present study aimed to investigate the latency of gaze direction, using an ERP decoding approach, based on the combination of a support vector machine and error-correcting output codes. We recorded EEG in 40 young healthy subjects performing gaze detection task. The task presented 3D realistic faces with five different head and gaze orientations each: 30, 15 degrees to the left or right, and 0 degrees. While the classical ERP analyses did not show clear gaze direction effects, ERP decoding analyses revealed that discrimination of gaze direction, irrespective of head orientation, started at 160 ms and reached its peak at around 500 ms after stimulus onset. These findings suggest that as early as 160 ms our brain establishes the decoding of gaze direction.

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An EEG mu study of observed dyadic actions with varying agent involvement

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Observation of others' actions activates motor representations in sensorimotor cortex. Even though real-world action observation often involves multiple agents displaying varying degrees of action involvement, most lab studies on action observation investigated individual actions. We recorded EEG-mu suppression over sensorimotor cortex to investigate how the multi-agent nature of observed hand/arm actions is incorporated in sensorimotor action representations. Hereto we manipulated the extent of agent involvement in dyadic interactions presented in videos. In all clips, two agents were present, of which agent-1 always performed the same action, while the involvement of agent-2 differed along three levels: (1) passive and uninvolved, (2) passively involved, (3) actively involved. Additionally, a no-action condition was presented. The occurrence of these four conditions was predictable thanks to cues at the start of each trial, which allowed to study possible mu anticipation effects. Dyadic interactions in which agent-2 was actively involved resulted in increased power suppression of the mu rhythm compared to dyadic interactions in which agent-2 was passively involved. The latter did not differ from actions in which agent-2 was present but not involved. No mu anticipation effects were found. The results suggest that the sensorimotor representation of a dyadic interaction takes into account the simultaneously performed bodily articulations of both agents. However, no evidence was found for incorporation of static articulated postures of agents involved in the interaction.

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Poster session 15. Eye Movements - II

Suppression of ocular following responses to brief background motion in the reafferent direction

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When tracking an object moving against a textured background, the background retinal image moves opposite to the smooth pursuit eye movement direction. Ocular following responses to background motion in the direction of this reafferent signal are suppressed compared to motion in the direction of pursuit. We varied the contrast of the background to tell apart two accounts of why this suppression is observed. A visuomotor gain account, which predicts that ocular following is suppressed in the same proportion at every contrast level, and a sensory attenuation account, which predicts that larger contrasts are needed to elicit the same response. The background consisted of low spatial frequency gratings (0.22 c/deg) oriented either vertically or horizontally, with seven different contrast levels. During the pursuit of a dot moving horizontally at a constant speed (10 deg/s), the background drifted for a brief time (80 ms) at a high speed (57 deg/s). We show a very strong suppression of ocular following in the reafferent direction that can be mostly explained by a change in visuomotor gain and not sensory attenuation. An unexpected finding is that ocular following responses to background motion in the pursuit direction are about twice as fast as those to background motion in an orthogonal direction. Therefore, the asymmetry between ocular following in the reafferent and pursuit directions is caused by a change in visuomotor gain that enhances responses in the pursuit direction and suppresses those in the reafferent direction relative to an orthogonal direction.

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A preliminary study on evaluative responses toward naturalistic food images among patients with schizophrenia and healthy controls

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Introduction: Schizophrenia (SZ) is a severely debilitating mental disorder that affects visual information processing. Compared to eye movements of healthy controls (HC), comprehensive clinical investigations have reported that the gaze behavior of patients with first-episode and chronic SZ is abnormal (Wolf et al., 2021). While eye-tracking technology has existed for a long time in the clinical domain, few investigations have combined it with decision-making paradigms, providing additional information channels for examining clinicians.

Methods: The presented framework is a preliminary study among patients with SZ on their evaluative responses toward naturalistic food images (Wolf et al., 2018 & 2019). Two tasks (Liking and Shopping) were investigated to understand better the interplay between vision and cognition. In the Liking task, participants were asked to rate each image from 1 ("not like at all") to 3 ("like very much"). In the Shopping tasks, participants were instructed to express their judgment by picking a maximum of 7 images to their 'shopping basket', with a response set of 1 ("leave it"), 2 ("postpone judgment"), and 3 ("put in").

Results: In both tasks, the relationship between rating and actual viewing time differed between patients with SZ (N=24) and HC (N=30). For example, in the Shopping task, a significant inverted U-shape trend has been reported among HC (i.e., images labeled as 'wishlist' were associated with the longest actual viewing time). However, such relationship could not be observed among patients with SZ, who faced indecisiveness while being requested to make a more subjective choice.

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Maintaining fixation by children in a virtual reality version of pupil perimetry

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The assessment of visual field sensitivities in young children continues to be a challenge. Children often do not sit still, fail to fixate stimuli for longer durations, and have limited verbal capacity to report visibility. We investigated the use of a head-mounted VR display, gaze-contingent flicker pupil perimetry (gcFPP), and three fixation stimulus conditions to determine best practices for optimal fixation and pupil response quality. A total of twenty children (3-11y) passively fixated a dot, counted the repeated appearance of an animated character, and watched an animated movie in separate trials of 80s each. We presented large flickering patches at different eccentricities and angles in the periphery to evoke pupillary oscillations (20 locations, 4s per location). The results showed that gaze precision and accuracy did not differ significantly across the fixation

conditions but pupil amplitudes were strongest for the dot and count task. We recommend the use of the fixation counting task for pupil perimetry because children enjoyed it the most and it achieved strongest pupil responses. The VR set-up appears to be an ideal apparatus for children to allow free range of movement, an engaging visual task, and reliable eye measurements.

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Fixation classification: how to merge and select fixation candidates

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Eye trackers are applied in many research fields. To give meaning to the eye-tracking data, researchers have a broad choice of classification methods to extract various behaviors (e.g., saccade, blink, fixation) from the gaze signal. There is extensive literature about the different classification algorithms. Surprisingly, not much is known about the effect of fixation and saccade selection rules that are usually (implicitly) applied. We want to answer the following question: What is the impact of the selection-rule parameters (minimal saccade amplitude and minimal fixation duration) on the distribution of fixation durations? To answer this question, we used eye-tracking data of high and low quality and seven different classification algorithms. We conclude that selection rules play an important role in merging and selecting fixation candidates. For eye-tracking data with good-to-moderate precision (RMSD < 0.5°), the classification algorithm of choice does not matter too much as long as it is sensitive

enough and is followed by two rules: 1) select saccades with amplitudes > 1.0°, and; 2) select fixations with durations > 60 ms. Because of the importance of selection, researchers should always report whether they performed selection and the values of their parameters.

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Gaze deployment during aging in predictive and unpredictive environments

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When interacting with the environment, humans typically shift their gaze to positions of interest before executing body movements. With increasing age, both motor execution and sensory sampling are compromised. Older adults may compensate for their compromised vision by relying more on prediction or by increasing visual sampling by looking around more. To investigate such age-related compensation, younger (18-35 years) and older (>55 years) healthy adults fixated a cross on a screen, and upon its disappearance searched and reached for a visual target presented at one of two possible target positions. Target visibility was individually tailored through a psychophysical forced-choice experiment.

The target position was either random (50/50), biased (80/20), or predictable (100/0), in different blocks of trials. We expected saccades to the target to be earlier (including predictive saccades) when it was possible to predict where the target would be, and overall, more saccades before fixating the target during search in less predictable conditions. If older adults rely more on predictive strategies, the difference in saccade latency across conditions should be more pronounced for this age group. If they rely more on active sampling, they should perform more saccades during the search period of less-probable conditions. Preliminary results confirm that saccades to the target had shorter latencies when the target position was predictable, but they were generally longer in older adults. Participants made more saccades when the target position was less predictable. This was more pronounced in older adults. Thus, aging appears to primarily result in increased visual sampling.

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Eye movements during gaze perception

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Humans are interested in gaze and gaze direction, and in particular whether gazes are directed at them or have other targets. Gaze direction research has clarified some of the mechanisms underlying gaze perception, but little is known about the active exploration of another person's face during the task to see whether this person looks at the observer. An eye tracking experiment found that observers mostly fixated both eyes of the looker model and sometimes even repeated the scanning of the looker's eyes. No direct gaze bias – to assume that gaze is directed at the observer – realized; in contrast, visiting the second eye was more probable when the first visit was on a straight eye than on an averted eye. A third main result was that there was no regularity in the final fixation, failing the expectation that the final fixation would be on the abducting eye that is reported to dominate gaze direction judgments. The active looking behavior during gaze perception is interpreted as information gathering. It is apparently

not designed to use minimal information, but seems to seek redundancy to reduce uncertainty

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Irissometry: effects of pupil constrictions on iris elasticity and eye position estimations measured with video-based feature tracking.

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It is unclear how the iris deforms during changes in pupil size. Here we report an application of a multi-feature iris tracking method to measure iris deformation and its effect on eye position signals. To evoke pupillary responses, we repeatedly presented visual and auditory stimuli to healthy participants, while we additionally recorded their right eye with a macro-lens equipped camera. We tracked changes in iris surface structure between the pupil- and sclera border by calculating local feature densities (distance between feature points) across iris regions. The time analysis of densities showed that the inner regions of the iris stretched more strongly as compared to the outer regions of the iris during pupil constrictions. The iris deformations as a function of eccentricity and pupil size showed highly similar patterns across participants, highlighting the robustness of this elastic property. Furthermore, iris-based eye position detection led to more stable signals than pupil-based detection. The elastic property of the iris and instability of the pupil border explains eye-movement- and pupil-size-induced position errors in pupil-based eye-tracking. Tracking features in the iris likely produces more robust eye position and pupil size signals. Irissometry may pave the way to novel eye-trackers and eye-disorder diagnostics.

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EyeLab: a user-friendly Matlab graphical user interface for real-time eye movements studies

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The study of eye movements is a source of useful information to both basic scientists and clinicians. To visual scientists, eye movements provide a powerful research tool to investigate how the brain works. To clinicians, abnormalities of ocular motility frequently provide diagnostic clues.

The inputs and outputs of the oculomotor system are easy to measure and allow us to regard it quantitatively in a way that is not possible in other types of movements. In many cases, a few quick measurements of eye movements can provide as accurate a neurological diagnosis as a brain scan.

Despite the advantages of objective analysis of oculomotor functioning and the continuous progresses in eye-tracking technologies, eye-movement studies are likely confined to research laboratories and seldom applied in the clinical practice. The neurologist's expertise in reading the traces from eye-trackers, along with the specialized technical expertise required to manage, program and use such tools, hampered their widespread adoption.

EyeLab is a new MATLAB toolbox developed for the analysis of both saccadic and smooth pursuit eye movements while using the Eye Link II eye-tracker by SR Research. EyeLab extends its functionalities by managing a real-time monitoring user-friendly interface, which also allows personalizing the experimental procedure and managing data acquisition, visualization, processing, and storage, without requiring programming skills to the user. The real-time features enable the adaptation of the experimental protocol to the ongoing results. A showcase of the EyeLab functionalities, including data post-processing, reveals the potentialities of this tool for the neurological research and clinical practice.

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Poster session 16. Temporal Processing

Representational dynamics of neural selectivity for faces, bodies, and animacy

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Human visual processing is a remarkable fast process that allows us to correctly identify objects already from 100ms onwards. The occipito-temporal cortex (OTC) is a well-studied region for its involvement in object processing, and does not only consist of regions selective for distinct categories, but also provides evidence for clustering of these categories along more abstract dimensions. In this EEG study (n=25), we examined the temporal dynamics of two factors that are considered important for OTC organization, the face/body distinction and animate/inanimate division. Using multivariate pattern analysis (MVPA), we tried to unravel the independent contribution of both

factors, as well as perform single stimulus decoding. Our results show higher-than-chance accuracy for both factors, with face/body decoding reaching peak accuracy around 150ms and declining strongly over time. Accuracy for animacy decoding was never as high, but stayed consistently significant over the whole trial. Single stimulus decoding also displayed a strong peak, around 100ms after stimulus onset, with a steady decline afterwards. Comparison with theoretical models showed the strongest contribution of the face/body distinction, however taxonomy could significantly explain the data in later timepoints. When correlating fMRI data with our EEG data, we observed that early decoding is strongly related with V1 processing, whereas in later stages lateral and ventral OTC became more involved. These findings are consistent with the hierarchical nature of visual processing and provide support for an OTC organization where the animacy dimension and the face/body distinction both play a role with overlapping, but not identical temporal dynamics.

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Temporal binding windows for rhythmic and quasi-rhythmic audio-visual stimuli

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Multisensory stimuli are highly likely to be perceptually integrated even in presence of temporal asynchronies, within the boundaries of temporal binding windows (TBWs). In the audio-visual domain, psychophysical studies on TBWs employed different stimuli, such as flash/beep or complex speech signals. They showed that the width of TBWs grows as a function of the stimulus complexity; however, the key parameters contributing to this TBWs malleability have yet to be identified and the (quasi)rhythmic features embedded in natural scenes are among the potential candidates. We collected a large psychophysics set of data online (N=183) to investigate how TBWs change during the processing of dynamic audio-visual stimuli with different rhythmic properties. In Exp. 1 and 2, we used a simultaneity judgment task with pulsing audio-visual stimuli in which circles size and sound amplitude varied following a sinusoidal function at 1, 2 or 3 Hz. In Exp. 3, we compared simultaneity judgments for rhythmic and quasi-rhythmic (speech-like) audio-visual stimuli, comparable in terms of average frequency (3 Hz). Results suggest that TBWs shrink as the stimulus frequency increases (Exp. 1), even when stimuli are equalized for the number of pulses (Exp. 2). Additionally, quasi-rhythmic speech-like stimuli are integrated across a wider TBW only when the auditory presentation preceded the video (Exp. 3). In conclusion, the frequency of rhythmic stimuli has an impact on audio-visual integration, resulting in different TBWs sizes. Stimulus spectral complexity might account for larger TBWs for quasi-rhythmic stimuli, which putatively require deeper processing in the auditory modality before being cross-modally integrated.

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Visually evoked potentials from stimuli beyond the flicker fusion threshold allow for comfortable control of a computer

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In many brain-computer interfaces, the user fixates at a flickering stimulus on a computer screen. Visual evoked potentials are recorded using electroencephalography and classified using machine learning methods. This enables the system to determine at which stimulus the participant is fixating. Stimuli are usually high-contrast white-black patterns, alternating at low-frequency (e.g., 15 Hz). However, such stimuli could cause visual fatigue or even epileptic seizures, and are therefore not suited for user-friendly applications. To improve on this, we used stimuli that flicker at higher frequencies (beyond the flicker fusion threshold). With N=7 participants, we explored candidate stimuli that flickered at 120 Hz for a duration of 3 s. Stimuli were (a) alternating white-black rectangles (perceived in superposition as gray), (b) an alternatingly high vs. low-pass filtered image (perceived in superposition as unfiltered image), (c) an alternatingly black vs. white-shifted image (perceived in superposition as a gray veil over the image) and (d) a red-blue stimulus (perceived in superposition as magenta). All stimuli were presented in two variants, phase-shifted by pi relative to each other. A regression-based machine learning model detected the phase shift with accuracies (mean +/- between-subjects SEM) of (a) 83.0% +/- 2.9% (b) 64.5% +/- 5.3% (c) 86.8% +/- 3.3% (d) 61.6% +/- 5.7%. Focusing on stimulus variant (c), we achieved in a follow-up experiment with N=7 participants an accuracy of 91.5 +/- 2.6%. Such high accuracies are promising for applications. For example, the control of a modern computer desktop where all elements (icons, buttons, etc.) can be replaced.

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Effect of motion on apparent timing of visual events

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The apparent duration of accelerating sine gratings is compressed. It has been proposed that fast adaptation of temporal processing to changes in temporal frequency content is responsible for the effect. Here we ask whether these effects are accompanied by changes in the apparent time of gratings' offsets (Experiment 1), and whether the effects persist thereafter (Experiment 2).

In Experiment 1, two drifting sinusoidal gratings were presented on each trial, at the either side of the fixation. Participants (N=9) estimated whether the standard grating (accelerating: 0-20, 5-15 deg/sec, or decelerating: 15-5, 20-0, 40-20 deg/sec; duration 900 ms) disappeared earlier or later than the test (10 deg/sec, variable duration). The accelerating gratings were perceived to disappear earlier than decelerating gratings. However, a control experiment suggested that the final speed, rather than speed profile is responsible for the effect.

In Experiment 2, participants (N=6) were first presented with two drifting gratings. Then, two black Gaussian patches were presented (50 ms), with variable stimulus onset asynchronies. The test stimulus was presented at the location of the grating drifting with constant speed of 10 deg/s, and the standard at the location of accelerating (0-20 deg/sec), decelerating (20-0, 30-20 deg/sec) or gratings drifting at constant speeds (0, 1, or 20 deg/s). We found little evidence that short term adaptation to a drifting grating changes the perceived time of occurrence of the subsequently presented stimuli.

In sum, the apparent offset time of drifting gratings is affected by their speed, but the changes reset after the gratings' offset.

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Localisation biases at the onset of moving objects of variable durations

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In the Fröhlich effect, the initial position of a moving object is mislocalized in its direction of motion. Several explanations have been proposed, including an extrapolation into the future to account for neural delays and an interaction between focal attention and metacontrast. While all these explanations account qualitatively for the Fröhlich effect, few can be considered good quantitative models. One critical test of any model is the effect of the motion duration. As early as 1930, Rubin noticed that reducing the motion duration decreases the magnitude of the spatial bias. This motion duration property of the Fröhlich effect is a challenge for all existing models that predict little or no effect of duration. We carefully measured localisation biases at the onset of moving objects in a psychophysical experiment using a forced-choice method. To reduce the effects of spatial and temporal predictability, two vertical lines were flashed one above the other at random spatial locations and random times. One of the two lines was set in motion as soon as it appeared, and the other remained static. Observers were instructed to report which line was to the right of the other one. Spatial offsets were controlled by interleaved staircases. We found that the magnitude of the spatial bias increases greatly with motion duration and motion speed. The effect of duration on bias magnitude is well fit by a scaled cumulative function of the exponential distribution. We discuss the implications of this motion duration property for models of the Fröhlich effect.

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Effect of Spatial Cueing on Haptically Perceived Time at Human Torso

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Directing attention to a specific location through exogenous or endogenous cueing improves the processing by allocating resources to that location. Attentional processes also affect temporal judgements: spatial cueing which directs attention to a specific location has been found to expand perceived time of stimuli in visual and auditory modalities. In the present study, we investigated attentional effects on haptically perceived time when judging vibrotactile stimuli at the human torso.

In a temporal bisection task, participants were presented first with a spatial cue pointing to either the left or the right side of the torso and then with a haptic stimulus (duration: 300 – 800 ms) at the congruent side of the torso. Spatial cues were brief vibrotactile stimuli (14.5 m/s2 acceleration amplitude, 100 ms) given through a haptic vest at the left or right front side of the upper torso , visual flickering dots (1.8° visual angle, 100 ms) presented at the left or right side of a screen in front of the participant, or in a control condition no cue was given. We found that haptic cueing extended the perceived duration of the haptic stimulus as compared to no cueing, but visual cueing did not have this effect. The results indicate that attentional processes can influence perceived timing in the haptic modality at the human torso. The lack of effect of the visual

cue might be due to the spatial separation between visual cue and haptic stimulus.

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Neural entrainment promotes audio-visual integration for rhythmic stimuli together with endogenous alpha speed

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Temporal binding windows (TBWs) are time windows in which multisensory stimuli are bound into a single percept, even when presented with significant temporal asynchronies. It has been suggested that brain oscillations in the alpha band might represent one of the basic temporal units of visual processing and audio-visual integration. However, the relationship between TBWs and alpha oscillations has been typically investigated using basic flash/beep stimuli, which do not entail neural entrainment (phase alignment), fundamental for processing sensory stimuli with rhythmic/quasi-rhythmic features that are intrinsically embedded in natural environments. Here, we study the role of neural entrainment to rhythmic stimuli in modulating audio-visual integration and TBWs, and the potential link with endogenous alpha rhythms. EEG data (N=31) were collected at rest and during a simultaneity judgement task with audio-visual stimuli pulsing at 2 and 3 Hz at different stimulus onset asynchronies. Results showed that participants with faster endogenous alpha had narrower TBWs (higher audio-visual temporal acuity) and also exhibited higher neural entrainment to audio-visual rhythmic stimuli. Furthermore, higher neural entrainment was found for trials where participants judged the audio-visual stimuli as synchronous despite being physically asynchronous. This pattern emerged more clearly when the visual stimulus was presented before the auditory one. Overall, our findings show that endogenous alpha oscillations are linked to TBWs and to the strength of neural entrainment for complex rhythmic stimuli. They also suggest that neural entrainment toward sensory stimulation promotes audio-visual integration, with visual modality having a pivotal role in this process.

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Faster phonological decoding in dyslexic adults induced by action video games and transcranial electrical stimulation of the posterior parietal cortex

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It is often said that reading speed in dyslexics adults cannot improve, not even after focused remediation trainings, because of a reduced neuroplasticity.

However, different techniques of transcranial electrical stimulation seem to be able to enhance the reduced neuroplasticity that characterise the adult's neural system.

Moreover, an increasingly growing scientific literature seems to demonstrate the effectiveness of action video games in enhancing multisensory mechanisms, such as visual attention and phonological working memory, in children with dyslexia.

In this study, 20 adults with dyslexia followed an action video games training for 12 hours. Pseudowords reading (i.e., phonological decoding), temporal visual attention (i.e., attentional blink) and phonological working memory were measured before and after the training.

Half of the participants stimulation (tRNS group) were stimulated with a bilateral transcranial random noise of the posterior parietal cortex during the action video games training. Even though the other half of the participants believed to be stimulated (to check the presence of the placebo effect), they were not (i.e., "sham" condition).

Results demonstrated that only participants in the tRNS group, at the end of the training, showed a faster phonological decoding that could be explained by the enhancement in the temporal visual attention and the phonological working memory induced by the training.

Our results show a strong causal link between deficits in multisensory attentional mechanisms and reading deficits.

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The influence of category deviations on the temporal oddball effect

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Visual events are sometimes perceived to last longer or shorter than they actually are. Studies have shown that a novel stimulus embedded in a sequence of repeated stimuli

is perceived longer than the repeated stimuli presented for the same duration. This phenomenon, known as the oddball effect, has been suggested to reflect repetition suppression at the neural level. However, it is still unclear which processing stages in the visual system are important. In this study, we examined the role of high-level visual processing in the oddball effect by manipulating the consistency of face category between repeated and oddball stimuli. We presented either a human, monkey, or cat face as an oddball after repeated presentation of an identical human face and found that the oddball effect was stronger when the oddball was a monkey or cat face than when it was a human face. The difference was preserved even when we presented a series of different human faces before the oddball, indicating that the changes in face category from the preceding stimuli caused stronger duration distortion. Furthermore, control experiments using Fourier phase-scrambled face images where configural information was eliminated confirmed that the difference in low-level visual properties of the stimuli could not fully explain the influence of category change. Our findings indicate that high-level visual processing in areas selective for face category may play an important role in the oddball effect.

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Flicker-induced time dilation does not depend on the phase of visually-entrained alpha oscillations

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The perceived duration of flickering stimuli is prone to overestimation. Whether neural oscillations concomitant with the flickers play a role in such time distortions is debatable. In this study, by placing flickers in phase or out of phase relative to the entrained alpha rhythm (10 Hz) and simultaneous EEG recordings from participants (n = 14), we assessed how the phase of neural oscillation affects the flicker-induced time dilation (FITD). Furthermore, in order to control for the effect of temporal expectancy and masking, two additional conditions were added. Analysis of time reproduction data indicated that irrespective of conditions, FITD was replicated (main effect of stimuli: static versus flickering), and duration of the stimuli (static and flickering) presented in phase was more overestimated than the ones presented out of phase (main effect of phase). More importantly, however, there was no interaction between stimulus type, phase, and the entraining condition, meaning the amount of FITD was similar for the in phase and out of phase presentation of stimuli across all conditions. Finally, EEG analysis confirmed that the power of 10 Hz oscillations was significantly higher in the alpha entraining condition. Moreover, only in the alpha entrainment condition, the phase distribution of in phase and out of phase flickers were non-uniform and locked to opposite directions affirming that flickers were presented at expected neural timings and were organized only in the alpha entraining condition. Overall, our results suggest that oscillatory cycles of excitation, entrained by the visual context, have no impact on FITD.

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Poster session 17. Memory & Learning

Input Variability During Perceptual Learning Taps into Invariant Representations to Enable Generalization

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Visual Perceptual Learning (VPL) is the improved detection or discrimination performance following training. It has been shown that VPL is highly specific, i.e., even a slight alteration of training stimuli lets performance drop to pre-training levels. Because of this specificity, researchers have suggested that VPL relies on sharply tuned neurons in early visual cortex. However, more recent studies report that VPL can generalize, questioning this classical interpretation. We hypothesize that VPL can tap into higher-order neurons that display invariance properties along multiple stimulus dimensions. We designed an orientation discrimination task in which we could independently manipulate stimulus difficulty and task-irrelevant variability (in spatial frequency). Four groups of subjects were trained in high and low precision/variability conditions for several days. After training, all groups were tested with new spatial frequencies and at a new location. Our results show that low task difficulty and high task-irrelevant variability both enable generalization. To investigate possible mechanisms underlying generalization, we implemented a Deep Neural Network and trained it with the same stimuli. We find that variability also enables generalization in this network. Generalization was correlated with a significant increase in spatial frequency-invariant orientation tuning of the network units. These results suggest that VPL can generalize if training taps into neuronal invariances in vivo and in silico.

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Effectiveness of Action Video Games Training in Children with Developmental Dyslexia: A meta-analysis

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Dyslexia is a multifactorial neurodevelopmental disorder typically characterised by phonological and orthographic deficits. However, low-level sensory-processing impairments precede and underlie phonological and orthographic problems. Thus, a dysfunction of selective attention could be one key distal contributor to dyslexia. Meta-analysis approaches have shown that visuo-spatial attention is impaired in pre-literacy, beginner and advanced readers with dyslexia, and that children with dyslexia have a universal attentional network dysfunction. Is visuo-spatial attention treatment effective in reducing reading difficulties in children with dyslexia? The goal of this meta-analysis was to investigate the effectiveness of visuo-spatial attention treatments with action video games, characterised by high perceptual and sensory-motor loadings without any phonological and orthographic stimulation. Nine randomised controlled trials involving children with a diagnosis of dyslexia were selected. The results of this meta-analysis demonstrate the effectiveness of action video games treatment in children with dyslexia. The impacts of this training not only affect visual attention (g=0.72, the primary outcome) but, more importantly, also extend over cognitive functions not directly trained, such as reading speed (g=0.44), phonological skills (g=0.45, phonetic discrimination and short-term phonological memory) and cross-modal abilities (g=0.4, rapid automatisation naming). These improvements highlight a clear role of selective attention in reading skills development and the generalisation effects of action video games training. The clinical application of action video games enables effective, fun and engaging treatment of dyslexia.

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Sequential visual encoding guides planning of the potential future in working memory

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Visual working memory enables us to retain visual information to prepare for the potential future. Previous research has shown that planning for the upcoming use of a visual representation in working memory starts immediately upon sensory encoding, rather than building up gradually. Here we ask whether this is also true for the encoding of multiple visual items, that may potentially guide upcoming behavior. Human participants performed an orientation-reproduction task, where multiple visual items were presented sequentially, and either one or two items were selectively retained by the participant. Item orientations (left/right tilt) were linked to specific manual actions (left/right hand), and their mapping was counterbalanced. We tracked contra- versus ipsilateral attenuation of beta-band activity – a canonical motor-cortical EEG signature of planning – during the memory delay. We show that potential future actions are planned alongside the sequential encoding of visual items into working memory. Crucially, this does not only occur when a visual item is certain to guide future behavior (i.e., in load one), but also when it may potentially guide future behavior (i.e., in load two). Moreover, the degree to which one of these potential actions is planned, is also predictive of the speed of behavior seconds later. These findings support the notion that the prospective use of a visual representation in working memory is planned early on, even when this regards the potential (rather than certain) prospective use. By considering the potential future early on, we may be optimally prepared for behavior in our dynamic world.

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The role of top-down influences on the magnitude of the oblique effect

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Visual perception can be biased by prior experience. For example, the well-known oblique effect (OE: we are better at seeing horizontal and vertical edges than oblique ones) may reflect the relative frequencies with which different orientations occur in the world. However, the precise mechanisms underlying the OE remain uncertain. Although low-level explanations emphasise population anisotropies in orientation-selective neurons in V1/V2, other findings point to high-level, top-down influence. For example, larger OEs when oriented stimuli are presented sequentially, rather than simultaneously, suggests a visual memory contribution. To investigate top-down influences we conducted two experiments. In Experiment 1, observers performed temporal and spatial versions of a two-alternative-forced-choice (2AFC) orientation-identification task. They identified which of two Gabor stimuli (1 c/deg, 40 % contrast, 0.3 s duration) was the target orientation (0, 90, -45 or 45 deg). Thresholds showed robust OEs of similar magnitude for both tasks, but markedly larger than typically reported estimates. Presenting stimuli sequentially does not guarantee larger OEs, suggesting previous findings should be interpreted with caution. In Experiment 2, we investigated whether the type of orientation judgment influences performance. Using a temporal 2AFC task, observers either identified which Gabor was

the target orientation (identification threshold) or was tilted more clockwise (discrimination threshold). OE magnitude was consistently larger for identification than discrimination judgements, consistent with greater uncertainty in the representations of learned oblique orientations. This suggests that high-level, top-down processes do play a role in generating the OE, independently of low-level orientation anisotropies in early cortical processing.

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Target-location rather than target-object specific saccadic selection in visual working memory

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Saccades, planned and executed while maintaining a stimulus array in visual working memory (VWM), improve memory for stimuli that had been presented at the saccade target. In two experiments, we investigated whether this spatially-specific memory advantage encompasses other locations that belong to the same object as the saccade target. In Experiment 1, we briefly presented an array of three oriented Gabors and five noise patches, spatially interleaved on an imaginary circle. In half of the trials, we displayed these stimuli inside of two objects, defined by simple contours surrounding four stimuli each. A movement cue, appearing 400 ms after memory array offset, instructed observers to saccade to the indicated location. Another 800 ms later, we prompted observers to report the orientation (clockwise vs. counterclockwise) of one randomly chosen memory item. Memory was best for stimuli that had been presented at the saccade target. For all other locations, memory was similar irrespective of whether they were presented in the same or different object as the saccade target. In Experiment 2, we added more object features to the stimulus. We observed better memory for stimuli presented in these complex objects as compared to objects formed by simple contours. Again, memory performance was best for stimuli seen at the saccade target, and similar across stimuli at all other locations, irrespective of whether they were located on the same object as the saccade target. Saccadic selection, therefore, does not encompass the entire saccade target object, indicating spatial, rather than object-based, saccadic selection in VWM.

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Change in the neural representation of novel and familiar objects over the course of recognition learning

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Much is known about the cortical representation of visual objects, but less about how such representations change while initially novel objects gradually become familiar. Here, we studied representation of identity, novelty, and familiarity of complex 3D objects in the whole brain during an object recognition learning task. Eight subjects observed a mixture of recurring and non-recurring objects and categorized each object as "familiar" or "unfamiliar" during six fMRI scanning sessions. Objects were presented either in fully random order (three consecutive sessions) or in restricted random order with temporal communities or episodes (three consecutive sessions).

Whole brain activity was recorded in 758 parcels (each with approximately 200 gray matter voxels), and for 9 TRs following each object presentation, the approximately 1800-dimensional multivoxel response was assessed with linear discriminant analysis. We show that identity of recurring objects can be decoded in both ventral and dorsal networks with an accuracy-gradient along the antero-posterior axis, with the most identity-selective parcels located in V1-V4 and inferio-temporal regions. We further show that representations of recurring and non-recurring objects are not stationary but grow apart as recurring objects become familiar, particularly in parieto-frontal and inferio-temporal regions. Finally, we show that the neural representations of recurring objects in the same temporal community are more similar in frontal regions, but more dissimilar in midbrain areas. The correlates of communities seem unstable and most pronounced at close temporal proximity.

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The Role of a Short-Term Visual Buffer in Localizing Objects

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When a visual probe is flashed inside a moving frame, the location of the probe is not judged relative to the world, but relative to the frame. This gives rise to a visual illusion, the "frame effect", where flashes at the same location on the screen appear widely separated when presented in a frame that is moving periodically back and forth.

Here we first test whether it is the physical or perceived displacement that produces the illusory shift. We used a "frame quartet": two frames alternated between

top-left/bottom-right and top-right/bottom-left displays that could be organized as either horizontal or vertical motion, while two visual probes flashed at the same physical location. Depending on which frame was attended, several perceptual organizations were seen. Overall, the illusory offsets were determined by the perceived direction and whether both flashes fell within the same moving frame.

We next tested whether the frame effect is limited to bi-directional motion. We presented frames continuously moving in the same direction with two flashes at the same screen location, but in different locations within the frame. Flashes were still seen as widely separated, demonstrating a frame effect for unidirectional motion. These results point to an important role of a short-term visual buffer in determining object location. We hypothesize that the positions of objects with high spatial uncertainty, like brief flashes, will be judged relative to a local frame that has more reliable spatial information.

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A Stroop-like effect endures in the short-term memory

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The Stroop effect is slowing down of naming the ink colour of a colour word, if the ink colour and the colour word meaning are incongruent. In the present study we implemented a variation of the Stroop paradigm to explore "endurance" of the Stroop effect, when the colour word and decontextualized colour are processed successively. A "primer" (presented for 500 ms) was either a colour word (RED, BLUE, GREEN) or coloured non-word XXXX (control condition); the ink varied as red, green or blue. After a mask (500 ms), a coloured disk, the target, followed (500 ms), which, too, varied as red, green, blue. In a same-different task, participants judged whether the ink colour of the "primer" matched the target colour. Each combination of the colour word/primer ink/target colour was presented 20 times; error rate and response times (RTs) were measured. Results showed that in the incongruent "primer" (colour word/ink colour) condition participants' error rate and RTs increased compared to the congruent condition. In the control condition, the error rate was comparable to that in the congruent condition but RTs were significantly shorter. The results provide evidence that the Stroop-like effect endures in the short-term memory. Furthermore, the increase of both behavioural measures in the incongruent, but not in the control condition, indicates the processing conflict between the meaning of the colour word "primer" and the colour of the target. This implicates semantic "translation" (covert labelling) of perceived colour of the target but only when the primer is a colour word.

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Oculomotor Rehearsal in Visuospatial Working Memory

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The neural and cognitive mechanisms of spatial working memory are tightly coupled with the systems that control eye-movements, but the precise nature of this coupling is not well understood. It has been argued that the oculomotor system is selectively involved in rehearsal of spatial, but not visual material in visuospatial working memory. However, few studies have directly compared the effect of saccadic interference on visual and spatial memory. We examined how working memory for visual and spatial features were affected by overt and covert attentional interference across two experiments. Participants were shown a memory array, then asked to either maintain fixation, or to overtly or covertly shift attention in a delay-period detection task. Using the continuous report task, we examined the precision of visual and spatial working memory representations and fit psychophysical functions to the data to examine the sources of recall error. There was no effect of interference on the precision of responses in either experiment. However, we found a significant increase in guessing responses following saccadic interference in memory for spatial locations compared to maintaining central fixation and covertly shifting attention. This effect was not observed when probing memory for colour. These data provide evidence for a specific and critical role of the oculomotor system in maintenance of spatial information in working memory.

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The efficiency of memory search depends on categorical target-distractor similarity

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During memory search, a single visually presented item is compared against multiple items in memory. Memory search can be considered the inverse of visual search, in which a single memory item is compared against multiple visually presented items. Previous research has shown

that memory search time increases logarithmically with memory set size, unlike visual search, where the relationship with visual set size is linear. Here, we test how the relationship between memory set size and reaction time (RT) depends on the categorical similarity between target (memorized) and distractor objects, both in short- and long-term memory tasks. Participants memorized 1, 2, 4, or 8 objects, all from one category (animate or inanimate). Subsequently, they performed an old/new recognition task, in which they had to indicate, for each object, whether it was part of the memory set. Analyses focused on RT to new (distractor) objects, which made up 80% (Experiment 1) or 50% (Experiment 2) of the presented objects. Importantly, half of the distractors were from the same category as the memorized set, and half were from the other category. Across conditions, results showed that reaction time (RT) varied logarithmically with set size. However, the slopes differed significantly between conditions, with steeper slopes for within-category than between-category distractors. Nearly identical results were found for long-term (Experiments 1 and 2) and short-term (Experiment 3) memory search. These results demonstrate that the efficiency of memory search depends on the categorical similarity between targets and distractors.

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Seeing to learn: vision correlates to math and reading performance

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Vision plays an important role in learning and development. It is often assumed that visual abilities influence students' performance, including the acquisition of arithmetic and reading skills. Here, we investigated arithmetic skills (addition, subtraction, multiplication), reading fluency, and basic visual abilities including near visual acuity (near VA, LEA SYMBOLS® near test #250800). We report results from two independent samples with a total of 105 elementary school students in third grade (sample 1 (S1): 35 students; sample 2 (S2): 70 students). Our results show correlations between near VA and subtraction (S1: $\tau = .22$, $p = .051$; S2: $\tau = .236$, $p = .010$) as well as between near VA and reading fluency (S1: $\tau = .30$, $p = .014$; S2: $\tau = .246$, $p = .007$), indicating that students with better visual acuity perform better in subtraction and fluent reading. S1 included 24 students with learning disorders (dyscalculia n = 4; dyslexia n = 10; combined n = 10). We found that more students with learning disorders showed lower near VA (m = 1.13 decimal VA; age-appropriate VA = 1.25) than those without learning difficulties (m = 1.49 decimal VA; $\chi2(3) = 9.969$, $p = .002$; Cramer's $V = .534$). Our study thus emphasizes the importance of visual abilities for learning and suggests a systematic link between vision and learning disorders in primary school children.

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Rule awareness in mice predicts capacity to generalize rules to new stimuli.

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The ability to apply acquired knowledge to new contexts brings clear advantages - when it is confined to appropriately similar situations. Successful behaviour must therefore balance utilizing known rules and acquiring new ones. Here we show that mice apply one of two learning strategies when faced with a visual discrimination task featuring increasingly varied stimuli: While some mice applied a learned rule to new stimuli without delay (generalizers), others repeatedly acquired a new rule for each new stimulus pair (re-learners).

To characterize these different learning strategies, we trained head-fixed mice to approach either horizontal or vertical grey-scale stimuli in a virtual environment, with the range of stimuli increasing gradually. The animals' capacity to generalize their learned orientation preference to new stimuli was predicted by their ability to predict trial outcomes for the original stimuli: Animals that behaved more hesitantly in incorrect than in correct trials, signaling uncertainty about their stimulus choice, were also better able to generalize their behaviour to new stimuli. This suggests that the degree to which different animals adhere to learned rules is a stable cognitive processing style that appears to apply across different contexts. Finally, we connect these two learning styles to neuronal response preferences in primary visual cortex.

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The role of confidence in visual perceptual learning in the absence of external feedback

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Visual perceptual learning can occur in the absence of external feedback. Here, we tested whether confidence about the validity of perceptual decisions could be the internal mechanism that can affect perceptual learning when there is no external feedback. Participants made decisions about the direction of motion of a random-dot kinematogram stimulus over five consecutive days. Every two decisions, participants reported their confidence about the accuracy of their perceptual decision using the confidence forced-choice method. We manipulated confidence by intertwining two conditions in which the signal-to-noise ratio is similar but the absolute evidence differs. The two conditions consisted in high- and low-density stimuli, where the number of both signal and noise dots was higher in the high than in the low-density condition. Using the method of constant stimuli (day 1) or a staircase (subsequent days), 65% and 85% correct thresholds were estimated at the beginning of each day. Confirming previous studies, we found that perceptual learning occurs in the absence of feedback. Moreover, increasing the absolute evidence while keeping the signal-to-noise ratio constant leads to overconfidence in the low-density condition in the majority of participants. Our results demonstrated that participants who could better relate confidence to their perception showed greater learning across five days. However, we found no significant difference in learning between the two confidence conditions. Altogether, our results suggest that in the absence of feedback, confidence can act as the only available feedback system, and can facilitate visual perceptual learning.

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Manipulating feedback to explore the factors driving working memory allocation

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Visual working memory (VWM) can be described as a limited resource shared between visual stimuli. Previous studies demonstrated that this resource can be flexibly allocated depending on task demands, e.g. to prioritize an item associated with greater reward or for which memory is more likely to be probed. However, other factors that could affect allocation in everyday life, such as feedback and internal uncertainty estimates, have not yet been explored. In this study, observers memorized two motion stimuli of different colours and later reproduced the motion direction of one item using an analogue report. In the first experiment, we manipulated task-relevance by cueing stimuli of one colour more often. We found observers dedicated more resources to the more frequently cued stimulus. Using a population coding model of VWM we showed that this strategy minimized average error across the experiment. In the second experiment, we subtly manipulated the feedback of the true motion direction given at the end of each trial, artificially increasing the error for items of one colour and decreasing it for the other. Participants were unaware of this manipulation, but it successfully altered the perceived difficulty of memorizing each stimulus. Counterintuitively, we found strong evidence that observers allocated more resources to the stimuli for which the feedback error was reduced, i.e. those perceived as easier to remember. Modelling confirmed that this allocation strategy was opposite to the one that would minimize error. These results may indicate an intrinsic bias in VWM allocation towards stimuli associated with rewarding feedback.

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Visual Short-Term Memory Load Impairs Visual Perception Within the Focus of Attention

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Perceptual load was previously shown to impair perception of irrelevant visual stimuli, causing inattentional blindness. Similar findings suggest that visual short-term memory (VSTM) load comparably leads to inattentional blindness to visual stimuli presented outside the focus of attention during memory delay. However, it is unclear if these effects persist when irrelevant visual stimuli are presented directly within the focus of attention. Here, we investigated whether taxing sensory capacity in high VSTM load impairs the perception of irrelevant visual stimuli presented within the focus of attention. We present behavioral data testing this hypothesis. Sixteen participants performed a delayed-change-detection VSTM task of either low (one colored square) or high (four colored squares) VSTM load. Participants responded to a visual stimulus detection task during the VSTM maintenance period. The detection stimulus (grey circle, diameter 0.5° -degrees of visual angle-) was presented at fixation, randomly in half of the trials at a predetermined, individual opacity threshold level. Strong evidence was found in favor of a difference in the detection task performance between high and low VSTM load. Specifically, high VSTM load (compared to low) leads to reduced detection sensitivity (d') of a visual stimulus during VSTM maintenance ($BF10 = 15.11$). The results supplement evidence of impaired perception of

stimuli outside the focus of attention due to VSTM load, demonstrating inattentional blindness effects of VSTM load on irrelevant visual stimuli presented at fixation. These findings support the account that visual memory and perceptual processes depend on shared neural mechanisms, drawing upon common capacity storage demands.

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Poster session 18. Colour

Attentional effects towards color categories based on paired associations

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Threat relevant items are important for our attentional system to process. Previous studies have shown that stimuli paired with threat can lead to attentional avoidance. However, it is unknown whether color-threat pairings can be generalized in a more categorical manner among colors. We investigated whether pairing a single color (e.g., blue) with a threat-relevant stimulus (spider outline) leads to avoidance, and if this effect can be generalised to any hues belonging to that color category. In a visual search task, participants were presented with 6 circles around fixation, half were either non-target orange and the others could be blue or green (DKL color space). Participants searched for a unique stimulus (e.g., spider or flower) among a combination of target-irrelevant items. Initially blue was paired 70% with the spider, while green was paired 70% with flower. In later blocks, frequency of pairings was equal and included a range of hues. Results demonstrated that for the blue-spider pairing, in later blocks reaction times (RTs) were significantly slower to the spider compared to the flower for the two different blue hues, however RTs did not differ for a color at the blue-green category border. Overall, this suggests that pairing one specific color with a threat relevant stimulus can interfere with attentional search in a categorical manner.

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Investigating neurophysiological evidence on the attentional capture by salient but task-irrelevant abrupt onset cues in difficult color search

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According to the Attentional Dwelling Hypothesis, task-irrelevant abrupt-onset cues capture attention in a stimulus-driven way, and attention then dwells at cue position until target onset. As a consequence, search can be facilitated for targets at cued locations (in valid conditions) relative to targets away from the cue (in invalid conditions). However, this cueing effect is behaviorally only present in reaction times and error rates during difficult search, not during easy search. In contrast, according to the Priority Accumulation Framework (PAF), cueing effects for irrelevant cues differ from cueing effects by relevant cues. Most critically, irrelevant cues do not lead to more dwelling and can rather lead to retrieval of cueing information after target onsets. In a series of experiments, we used both behavioral measures (i.e., cueing effects and distractor compatibility effects) as well as event-related potentials (i. e., N2pc effects) to investigate if task-irrelevant abrupt-onset cues elicited attention shifts and led to dwelling of attention. We found behavioral support for attentional capture of task-irrelevant cues, but only when search displays remained on-screen until response. Furthermore, we found no support for the Attentional Dwelling Hypothesis in the size of cueing effects as a function of search difficulty. In contrast, PAF was partly supported. Lastly, we discuss diverse cue-elicited, lateralized ERP components in light of top-down spatial attention effects. Conclusively, our results demonstrate that choices toward the implementation of experimental protocols can dramatically alter results on attentional capture of salient, but task-irrelevant abrupt-onset cues and conclusions drawn from them.

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Prior expectations influence memory precision for hues in photographs

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Using photographs as stimuli for memory experiments improves the ecological validity of findings. However, people have a priori knowledge or expectations about the content, which is difficult to separate from their memory performance. In the presented study, we measured the extent to which the precision of memory response is affected by the difficulty of guessing the original hue.

We collected a set of photographs, where we identified a small number of content areas (4 to 8 areas covering Md = 81% of image). In Experiment 1 (N=62), we presented the photographs in grayscale and asked participants to select the most appropriate hue for each area (while retaining the original saturation and lightness). Thus, we collected the data about baseline expectations and their variability.

In Experiment 2 (N=59), we presented each photograph in colour for 5 seconds. After showing a dynamic mask for 1 s, we asked participants to reproduce the original hues for each area. We evaluated the accuracy (mean absolute error) and precision (interquartile range) of responses.

We found that accuracy and precision were positively associated with the variability of baseline expectations. The areas with more narrow baseline expectations were remembered more accurately and yielded less variable responses. Our analyses accounted for other potential confounders like the extent of each area or its saturation.

Our results show that the reports on human ability to store information about realistic scenes may be biased by our ability to predict the scene content.

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Comparing color concept with emotion color preference using psychophysical interval scale and ranking order procedure

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278 Brazilians volunteers (mean age = 30; SD = 1.02), ranked 8 color squares according to their degree of (i) personal preference; and emotional content in an orthogonal opposed-polarity axes (ii) boring-exciting and (iii) tense-calm.

Data were analyzed based on the Thurstone's Ranking Order, that calculate the proportion of judgments that every stimulus is greater them other for every possible pair. These derived proportions were used to apply his Law of Comparative Judgment, using the Case V, that assumes equal dispersions for all stimuli.

Results shown the following scale values (SD units) for personal preference Blue = 1.62; Purple = 1.27; Green/ Red = 1.05; Orange = 0.91; Pink = 0.85; Yellow = 0.57; Brown = 0.0.

Correlation between color preference and color concept r = 0.70 (p = 0.05). Tense-preference r = 0.13 (p = 0.75); boring-preference r = -0.75 (p = 0.03).

Bluish hues are more preferred and yellowish less, in line with the literature. Very similar psychophysical distance for green and red hues on the preference scale was also observed in color concept measurement and could be interpreted as having similar cognitive salience value. The high negative correlation between color preference and boring-exciting means that higher the preference less the boring emotion.

In quantifying colors in emotional terms in a continuum interval scale, we better understand how perceptual information and personal preference are psychological represented. The simplicity and high precision of the procedure allow its applicability on large groups of different populations, in which comparisons are desired.

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Decoding of colour from EEG data driven by contrast and colour opponency

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Cortical hue representation has previously been investigated with neuroimaging and information decoding techniques. We examined the uniformity of the neural hue space as reflected in electroencephalographic (EEG) recordings by decoding cardinal and non-cardinal colours of the perceptual CIE LAB colour space within and across different levels of saturation. If the neurometric hue space exhibits perceptual uniformity, we expect similar decoding performance for cardinal and non-cardinal hues regardless of saturation. We recorded EEG from 15 observers who performed a shape oddball detection task. The shapes' colours were set to cardinal or intermediate hue directions in CIE LAB space - i.e. red, green, blue and yellow as cardinal and orange, lime, turquoise and purple as non-cardinal hues. Colours were nominally isoluminant and presented at a higher or lower saturation level. We found asymmetries in hue decoding at both levels of saturation, indicating that the neurometric hue space derived from EEG signals does not correspond to the perceptual CIE LAB space. Hues could be decoded more reliably within than between the two saturation levels, in line with the marked effect of contrast on EEG waveforms. Patterns in the confusion matrix indicated that both cardinal and non-cardinal hues were more confusable with their opposite (e.g. red and green; purple and lime) than with their neighbouring hues (e.g. red and blue/yellow; purple and orange/turquoise). These outcomes demonstrate that cortical colour representations as captured by EEG are highly influenced by opponency and saturation (i.e. contrast), rather than organised in correspondence to a perceptual hue circle.

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Colour constancy and visual cues in simultaneous identification of illumination and reflectance changes

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Colour constancy means the ability to perceive stable object colours under changes in illumination. We asked whether colour constancy depends on explicitly identifying the illuminant chromaticity and what kind of contextual cues support this identification.

We studied the simultaneous identification of illumination and reflectance changes with realistically rendered, abstract 3D-scenes. Two scenes were presented for 1000 ms, separated by a blank screen for 250 ms. Between the intervals, the illuminant chromaticity and/or the reflectance of a central stimulus changed towards blue, towards yellow, or remained the same. The observer's task was to identify both changes. Different stimulus conditions had different cues for illuminant estimation: A full-screen background of uniform reflectance, or either matte or glossy neighbouring stimuli presented against a black background.

We studied the patterns of errors in the responses to illumination and reflectance changes. Identification of illumination changes was reliable, and reflectance changes were rarely mis-identified as illumination changes. Illumination changes, on the other hand, were much more frequently mistaken for reflectance changes. To quantify these effects, we fit a two-dimensional signal-detection model to the data. Illuminant and reflectance mechanisms were modeled as vectors in the stimulus space. Compared to matte contextual stimuli, constancy was improved by a uniform background, and to a lesser extent by specular highlights in glossy contextual stimuli. These improvements were also confirmed by the modeling.

We conclude that a failure of colour constancy does not depend on a failure to identify illumination changes, but better illumination cues still improve colour constancy.

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Presaccadic dynamics of color context remapping

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In previous studies we found evidence for saccadic remapping of contextual color information (Schrader & Wachtler, ECVP 2021). To further investigate the mechanisms of contextual processing around eye movements, we measured the influence of color contexts briefly presented during saccade preparation on the perceived color of stimuli that were spatially and temporally separated from the context.

Colored context fields were shown near the initial fixation point and stimuli near the saccade target, or vice versa. Contexts were presented for 120 ms, followed after a gap of 40 ms by stimuli presented for 60 ms.

Subjects' responses indicated color shifts up to 10% of the cone contrast of the context, but crucially only for stimuli near the saccade target, with peak amplitudes for stimuli presented less than 50 ms before saccade onset.

These color shifts were much larger than shifts observed in a control condition without eye movements, but were similar in magnitude to shifts induced when stimuli were presented within the context region, thus indicating a transfer of context information around saccade onset.

The observed context effects could reflect a remapping process based on preparatory receptive field shifts before saccades.

The corresponding direction of transfer of visual information before the saccade implies remapping of the stimulus onto lingering context information.

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Correlated colour temperature matching in flickering white stimuli

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Short wave visible spectrum provides entertainment of physiological functions via non-visual input melanopsin containing ipRGC. LED technology ensure opportunities to implement circadian management in lighting. However, melanopsin stimulation might alter the correlated colour temperature (CCT) experience. Sources with stronger circadian activation would lead to yellowish percept and lower CCTs. In our approach, we try to find optimal cyan (470-490) and blue (460nm) components of white lights, which lead to similar white perception comparing to classic RGBW approach, but increasing implementation of circadian rhythm regulation. Our previous study (Zaģers&Fomins, ECVP 2021) showed that static matching of RGBW and RAGCB+ source produce significant difference in CCT perception, reducing CCTs with implementation of cyan spectral component. We developed new version of bright multiple cyan spectra containing LED light source providing up to 400 lx at the pupil plane to mimic realistic environment for the range of applicable CCTs of 3000K to 6500K. 20 subjects adjusted 30 Hz flickering white lights at the range of luminance. Light stimuli flickered between RGBW and RAGCB modes in one aperture. Results indicate yellowish adjustments for cyan component lights only for high CCTs at lower luminance. Adjusted spectra are analysed to develop a model based on known melanopsin and photopigment absorbtion functions. Spectral model is applicable for photopic conditions.

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Colour Memory In Daltonism

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Colour helps identifying and recognising objects, an ability compromised in individuals with colour vision deficiency (CVDs). When tested in perceptual tasks, CVDs provide results inferior to controls. Given such lifelong experience our question was could, and would CVDs, use their memory of previously seen colours. Apart from conditions with regularly presented colours, we included filtered colours, equating task difficulty for CVDs and controls.

Participants, 23 CVDs (deuteranopes/protanopes) and 23 age and gender matched controls performed 2AFC task. A single test colour presented on a white background was matched to simultaneously or successively presented colours, the perceptual and memory task, respectively. In CIE Lab space the colour pairs were chosen from three pseudo-isochromatic lines, with each colour chosen from an equal distance at the opposite side of the gamut plane, Euclidean distance between the plane orientations was 0.4. Stimuli colours were daltonised in two ways (enhancing the red-green contrast in the direction of isochromatic line; enhancing the blue-yellow contrast perpendicular to it) and on two levels (Euclidean distances 0.6 and 1.0).

In both perceptual and memory tasks, CVDs performed with lower accuracy (91.7% vs. 97.1%) and slower RTs (1236 vs. 1507ms). Daltonisation helped them to achieve results nearly identical to controls (with up to 800ms acceleration), especially in the perceptual task. The two types of daltonization were almost equally helpful. Most importantly, given the chance, CVDs appear able to remember and use colours in the same way as controls, suggesting that this cognitive ability is not lost despite lifelong sensory deficit.

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The colour appearance of real scenes under multiple illuminations

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Colour constancy algorithms for digital images typically aim to make the image look as if a neutral light illuminated the scene, removing the chromatic bias of the actual illumination. The assumption is that this processing - "colour correction" - will not only achieve constant colour descriptors for objects in the image but also match the colour appearance of the original scene for a completely adapted human viewer. We tested the extent to which typical colour correction algorithms match the colour appearance of real, complex scenes under varying illuminations. Real scenes with multiple chromatic surfaces including either a human model or painted portrait were staged in a lightroom, with the left-right halves illuminated by the same (single-source) or distinct (two-source) spectra. Participants viewed the scenes through a porthole and adjusted the chromaticity of a digital image of the scene, presented on an adjacent monitor, to match. No other light sources were present, and adaptation times were controlled. Participant matches were compared with outputs of 11 colour correction algorithms, including standard single-source and novel multiple-source algorithms. In all conditions, algorithm outputs deviated from human appearance matches, with highest deviations for "cooler" illuminations and scenes containing human models, and lowest for algorithms designed to correct for multiple illuminations. The results demonstrate the need for new benchmarks for colour correction algorithms based on the spectral and spatial non-uniformities of chromatic adaptation in complex scenes.

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Perceptual evaluation of decolorization algorithms to study subjectively appealing color contrast information

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Decolorization (grayscale) is a dimensionality reduction transformation that finds many computer vision pre-processing applications. Most of the existing decolorization algorithms, including the recent computationally-complex learning-based algorithms, aim to preserve subjectively appealing color contrast information in the decolorized images. However, this may not guarantee the best performance when utilized for succeeding applications. To achieve both goals, we recently proposed a novel decolorization algorithm, which uses two weighted-blending functions combining red (perceived warm) and blue (cool) channel in accordance with advance/recede effects and Helmholtz-Kohlrausch effect. We performed an experiment to compare different decolorization algorithms using various test images to evaluate our algorithm's performance. Participants compared a color test image (at the center) with the six

decolorized images of the test (surrounding the test image), each of which is processed by a different algorithm. Participants were asked to mentally visualize the test image in a "colorless world" and pick one decolorized image which resembles it the most. We compared : (i) simple color space conversion algorithms (CIELAB, YCbCr, Ours) and (ii) spatial contrast-based algorithms (including

iteration-based algorithms and machine-learning). The test image dataset consists of natural (objects, sceneries) and synthetic images (charts, maps). The results show CIELAB and Ours performed better on average, which confirmed the superiority of the perception-based algorithms. Spatial contrast-based algorithms performed worse, possibly due to artificial contrast generation, but had shorter selection times. Most importantly, no single algorithm outperformed others across the test images. We will discuss what constitutes the best decolorization based on all algorithms' performance.

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Carry over effect of global/local processing on color constancy

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The world that we see is not always the same. Previous studies have shown that global/local processing might change our perceived world. Additionally, it was suggested that a prior task involving global or local processing affects the performance of the following task related to global/local processing. Color constancy, in which an object's color is perceived as invariant to the color of the light source, is a phenomenon related to global/local processing. Color constancy allows an optical illusion in which perceived color differs depending on the existence of the surrounding color despite the fact that the physical color is the same, and global processing is expected to enhance this optical illusion. We examined whether a prior task related to global/local processing influences optical illusion involving color constancy. Twenty-seven participants performed a global/local Navon task, in which participants were required to read a large letter or small letters in a large size alphabet consisted of small alphabets. Subsequently, they engaged in a color-matching task. In this task, a small square with surrounding color was presented. Then, a test patch, which color was the same as the small square, was presented, and participants adjusted the color on the test patch to be perceived as the same color presented with surrounding color. The extent of optical illusion after the global Navon task was larger than that after the local Navon task ($t(26)=1.81$, $p=.04$, $r=.34$). Thus, prior global/local processing could influence color perception This study provides new insight into perception flexibility, especially regarding color perception.

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Visual performance under reduced mid-wavelength energy spectrum

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Visual performance is affected by chromatic aberration, and filtering out short wavelength information increases contrast sensitivity and contrast discrimination ability. The increases are possibly due to reduced chromatic aberration and consequently cause higher luminous transmittance at a wavelength around 550 nm, to which the human eye is most sensitive. In this paper, we used two pairs of customized glasses that either reduce or maintain the transmission of the wavelength between 520 and 600 nm to explore the role of chromatic aberration in visual performance under five tasks. First, we measured the contrast sensitivity function using tilted Gabor with various spatial frequencies (SFs; from 1.28 to 23 cpd), and the result showed reducing mid-wavelength information caused less sensitive in the middle range of SF (5.12~12 cpd). Second, we adopted the Farnsworth Munsell 100 Hue Test to investigate color discrimination ability and found that reduced mid-wavelength glasses decreased the discriminability along the yellow-blue axis but not the red-green axis. We also measured dynamic visual acuity by measuring the minimum gap of a moving "C" (1.15 m/s) that participants could correctly perceive. A motion coherence task with random dot kinematogram was also introduced to investigate dynamic visual perception. The result showed comparable performance between the two glasses for both motion-related tasks. Lastly, we measured stereoacuity at a viewing distance of 2 m and found similar performance for the two glasses. In conclusion, reducing mid-wavelength information or chromatic aberration though decreasing contrast sensitivity and impaired color discrimination did not deteriorate motion and depth perception.

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Reference Repulsion in Hue Perception

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Visual perception can be biased by contextual information. One phenomenon of contextual influence is reference repulsion: when subjects report the motion direction of a stimulus after comparing it with an explicit reference direction, the reported direction is systematically biased away from the reference (Jazayeri & Movshon 2007). In color vision, repulsion effects are known to result from colored surrounds. While the surround might implicitly play a

role as a reference, a systematic examination of the repulsion from an explicit color reference is still missing. We used a dual-task paradigm where the subjects were asked to estimate the average hue of a noisy color ensemble after discrimination between the average hue of the ensemble and an explicit reference hue. We found that subjects' perceived hues were systematically biased away from the reference hues. The repulsion effects showed smaller magnitudes and occurred in a smaller range around the reference than the biases induced by colored surrounds. The repulsive biases were up to a maximum of about 5 degrees of hue angle near the reference hue, and were larger for hue ensembles closer to the reference and with higher chromatic noise. The results are in line with the findings in visual orientation and motion perception, which suggests a general mechanism for contextual information processing and visual decision-making.

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Context-dependent computations for color constancy

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Virtual reality (VR) technology allows realistic, immersive and well-calibrated experiments on colour vision, while offering the flexibility to change reflectance and illumination properties on-the-fly. This allowed us to investigate the role of the spatial average color in a scene for color constancy.

We used Unreal Engine for rendering, and an HTC Vive Pro HMD for display. We photorealistically rendered a complex outdoor scene under a neutral and four chromatic test illuminations. In each trial, observers chose which one of 5 small lizards comes closest to being achromatic. Lizard colors under the test illuminants are chosen to reflect reflectance matches, tristimulus matches, or in between levels of color constancy. In a control condition, all cues to constancy were available. We used two experimental manipulations to keep the spatial mean color constant: (1) changes in the reflectance of common objects like rocks, water or trees, (2) floating spheres randomly placed in the scene.

We found that adding colored spheres into the scene had a modest impact on color constancy, while modifying the reflectances of the common objects massively impaired constancy.

This suggests that observers perform some scene segmentation before color constancy calculations. Alternatively, the highly saturated spheres could be regarded as outliers. Overall, they are not taken into account when calculating the average color. When the reflectance change is distributed across many objects, all of them are taken into account and it is, in fact, difficult to distinguish the scene with the chromatically biased reflectances and illuminations from a neutrally illuminated scene.

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31 August 2022

Symposium 8. From vision to attention: the development of visual perception in early childhood

Information detection across the developing visual field

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Over the last decades, it has been common to study infant visual information processing in simplified settings, presenting images within limited visual areas on standard computer displays. This is a simplification of a richer visual environment in which information derives from a wide visual field including more peripheral locations. Evidence shows that infants' peripheral vision is developing during the first postnatal year (e.g., Dobson, Brown, Harvey, & Narter, 1998; Maurer & Lewis, 1991). Nevertheless, most studies have relied on the presentation of flashing LED lights and, to date, little is known about social and non-social information detection beyond near-peripheral locations. Here we explored infants' sensitivities to different visual information across a wide field of view of 120°. Using a detection task, we aimed to measure the extent of the peripheral field in response to Gabor patches (Experiment 1) and face-like stimuli (Experiment 2) in 9--month-old infants. Face-like stimuli were produced by spatially filtering intact faces, whilst controlling for luminance, colour and contrast to match with the Gabor patches. Results revealed unequal detection performances across eccentricities, with successful detection rates up to

50° in response to non-social targets. Notably, performances were increased with face-like stimuli and detection rates dropped beyond 55°, with a marginal advantage for targets appearing in the left hemifield and no effect of stimulus orientation. These findings are key to understanding how social and non-social visual information is detected outside foveal processed space and are informative for the design of future infant studies across the visual field.

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The influence of crawling on visual spatial and visual emotion processing in infancy

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Previous research indicated that the ability to crawl could lead to changes in infants' cognitive as well as social abilities. Based on these findings, we investigated these relations more specifically and explored whether crawling affects infants' visual processing of object arrangements (Study 1) and of faces (Study 2). Study 1, examined whether crawling and non-crawling infants use different gaze behavior while encoding objects within a visual-spatial surrounding. We constructed an arena consisting of circularly arranged separate walls, on which different objects were placed (and removed) at different heights. 9-month-old crawlers and non-crawlers wore a head-mounted eye tracker and were pushed through the arena. Preliminary results suggest that crawlers looked longer at objects attached to the wall's lower parts and were more sensitive to changes in the objects' locations compared to non-crawlers. Thus, visual encoding and processing of the environment seems to be influenced by infants' crawling ability. Study 2, investigated whether crawling is also related to infants' visual processing of emotional facial expressions. Since the onset of crawling leads to many social changes, such as more negative emotions expressed by the caregivers, we tested whether crawlers are visually more sensitive to fearful facial expressions than non-crawlers. Results showed that crawlers detected a change in emotional facial expression as early as 50% fearful expression, while non-crawlers did not perceive this change until 60% of fearful facial expression. In sum, our findings support the idea, that crawling has a facilitating effect on visual perception in the spatial as well as social domain.

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The long-term development of visual motion perception in preterm and full-term infants

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During infancy, smart perceptual mechanisms develop allowing infants to judge time-space motion dynamics more efficiently with age and locomotor experience. This emerging capacity may be vital to enable preparedness for upcoming events and to be able to navigate in a changing environment. Little is known about brain changes that support the development of prospective control and about processes, such as preterm birth, that may compromise it. As a function of perception of visual motion, this paper will describe the neural correlates of prospective control in a longitudinal design, and discuss apparent weaknesses in typical dorsal stream functions in infants and children born too early and with very low birthweight.

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Fourteen-month-old infants' sensitivity to intention-encoding information in biological motion

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Recognising others' intentions is an essential part of social interactions. The information about others' intention can be encoded in their movement kinematics, that is, variation in their motion when performing an action. For instance, the way one grasps a bottle depends on whether one wants do drink or pour from it, and adult observers are able to perceive that difference and recognise the intention behind the action. How this ability develops in young children is still unknown. This large, pre-registered study investigates infants' sensitivity to intention-encoding information in the biological motion of grasping. Fourteen-month-olds were tested in a habituation paradigm designed to examine whether infants perceive a difference between two kinds of stimuli. Firstly, infants were presented with videos of grasping actions with one of two intentions: grasp-to-drink and grasp-to-pour. If they habituated (their look duration decreased to below 50% of initial attention), they were presented with two novel videos consecutively that either showed a grasp carried out with the same or different

intention during the test phase. The final sample will be determined using Sequential Bayes Factor design, or the data collection will be concluded in summer 2022. The current sample size is n=127 and the final results will be presented. We hypothesise that infants presented with a different intention grasp than before will show a different looking time during the test phase than the infants presented with grasps with the same intention. This would demonstrate that they perceive the difference in grasping motion that encodes the intention information.

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Attention in infancy: a data-driven perspective

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Attentional control in infancy has been postulated as foundational for the development later in life. To better understand the development of attention in infancy and how it is related to other functions or abilities, our first aim was to use a data-driven method and examine longitudinal eye-tracking data to establish stable markers of attention in infancy. Two attention indices showed a high degree of stability and internal consistency. Our second aim was to relate these attention indices to self-regulation in toddlerhood. However, we did not observe any significant correlation between attention in infancy and self-regulation at 18 or 30 months. Our third aim was to retrospectively examine the relation to potential risk factors, such as maternal adverse childhood experiences and psychological distress. We found that maternal exposure to non-interpersonal traumatic events in childhood was associated with less sustained attention of the infants at 6, 10, and 18 months. In addition, exposure to interpersonal traumatic events in mothers' childhood was identified as a moderator of the negative effect of maternal anxiety during the 2nd trimester on the development of sustained attention in infants. Our findings add to a growing body of research suggesting that a relation between attentional control and self-regulation is unsupported. Furthermore, we underscore the importance of maternal mental health to the development of sustained attention in infancy and address the need for early screening of maternal mental health during pregnancy.

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Pupil size as a marker of attention in typical and atypical development

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The assessment of pupil size poses a promising tool for the investigation of attentional mechanisms especially in young children and clinical populations, where acquisition of psychophysiological data can be challenging. We demonstrated that unexpected sounds, that involuntarily capture attention, lead to an increased pupil dilation response (PDR) already in 14-month-old infants. Pupil size is modulated by both the sympathetic and the parasympathetic pathway of the autonomic nervous system via two different muscles. We separated the contributions of both pathways to the PDR and found that the sympathetic component was sensitive to the arousing potential of distracting sounds and differed between infants and adults. Hence, our approach allows for the investigation of the effect of arousal on attention from a developmental perspective. This is also relevant with regards to developmental disorders like Attention Deficit/Hyperactivity Disorder (ADHD), where a disturbed arousal regulation has been discussed. The level of arousal can be modulated by the activity of the Locus Coeruleus-Norepinephrine (LC-NE) system. The LC is located in the brainstem and projects towards widespread regions including brain areas implicated in attentional processing. The pupil is closely linked to LC-NE-activity. We investigated slow changes of pupil diameter across a visual sustained attention task in children with and without ADHD. The pupil diameter was initially similar in both groups and decreased during the task in controls but not in children with ADHD. Our results indicate a dysregulation of the LC-NE system and an insufficient adaptation to the requirements of the task with time in ADHD.

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Symposium 9. Advantages of virtual reality developments for perception research

Supporting the design of educational application in VR through eye tracking

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Digital VR learning spaces have the potential to enable learning experiences that are more personalized, flexible, inclusive, and immersive at the same time. In the field of so-called experiential learning, intensive research is therefore being conducted on design paradigms for sustainable and efficient VR learning spaces. Also in the field of personalized learning, adaptive design of learning environments, and VR environments in particular, can enable highly realistic and interactive learning scenarios that can be configured in advance and adapted to the learner's abilities.

Eye-tracking integrated into these environments not only enables the collection of objective measures of the effectiveness of such learning spaces, but also provides an important modality for customization and personalization. In my talk, I will discuss the potential of eye-tracking technology in combination with machine learning methods for the sustainable design of learning environments and show selected examples of its application in real-world scenarios.

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Using immersive virtual environments for studying the visual guidance of action

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Research into the visual guidance of action has tended to either use highly constrained tasks, such as reach to grasp movements, or has struggled to generate effective experimental manipulations during more complex movement skills. In this work, we used the opportunity afforded by virtual reality to manipulate the physical properties of a bouncing ball to examine predictive visual behaviours during an unconstrained interceptive task. Active inference accounts of perception and action propose that actions are dynamically planned according to uncertainty about sensory information, prior expectations, and the environment, with motor adjustments serving to minimise future prediction errors. We tested whether predictive gaze behaviours are indeed adjusted in this Bayes-optimal fashion during an interceptive task. Participants intercepted bouncing balls under conditions of higher or lower environmental volatility, which was controlled by varying the physical properties of the bouncing ball. Participants' gaze patterns differed between stable and volatile conditions in a manner consistent with generative models of Bayes-optimal behaviour. Partially observable Markov models also revealed an increased rate of associative learning in response to unpredictable shifts in environmental probabilities. These findings have theoretical implications for active inference but also illustrate opportunities for studying more complex movement skills, as well as movement difficulties in developmental conditions like autism, by using virtual reality to manipulate environmental constraints.

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Visual search in 3D-modelled rooms: comparing results from the same protocol run in VR and on 2D screens

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A virtual reality headset is an incredibly useful experimental tool because it allows for unrestricted movements compared to on-screen protocols, giving experimenters full control over stimuli and measurements/tracking. Together with an eye tracking device, virtual reality opens the door to protocols that would have been impossible on-screen and very limited or laborious in field studies. However, eye tracking in virtual reality requires access to such equipment, particular programming knowledge and appropriate analysis skills. In a two-part study, we asked if gaze dynamics of visual search in VR could be replicated in more accessible online studies. We wanted to measure the suitability of online testing (without eye tracking) as a proxy for measurements of visual behaviors in 3D-environments. The protocol implemented had participants search for targets in fully-furnished 3D-modelled indoor rooms. Search targets were located in plain view or stored inside containers (e.g., closet). Participants could interact with containers to open and look inside them. In the online version of the protocol participants used their keyboard and mouse to control camera movement. Results from the VR and online study show comparable search performances. Interestingly, we show that camera movements in the online variant (keyboard/mouse) mimicked gaze properties. For example, camera velocity signals exhibited rests and peaks reminiscent of fixations and saccades. We processed camera motion signals as we would do for gaze signals to further compare virtual reality and online measurements and discuss the implications of this method to make it easier to study gaze behaviors in increasingly realistic, dynamic tasks.

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Use cases of eye-tracking in virtual reality (VR) for basic research

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The ease of implementing relatively simple virtual reality (VR) environments coupled with eye-tracking measures opens a new research context, besides screen-based and mobile eye tracking. In this talk, I will be briefly showing the gist of some recent, ongoing, or pilot experiments utilizing VR at the psychology department, whilst emphasizing on the development processes of these experiments. These studies often include comparing gaze patterns or distribution of fixations as proxy measures for visual attention. The selected examples of research will be using (i) virtual and real art galleries in empirical aesthetics, (ii) Gabor patches in visual attention and crowding research, (iii) immersive storytelling in experience design, (iv) interactive scenarios of daily tasks in visual search, (v) 360° recordings imitating real-life incidents in eye-witness research, (vi)

360° videos for the remote operators of autonomous vehicles in decision-making, (vii) social VR environments with digital avatars in non-clinical paranoia research. I will also briefly underline the advantages and challenges of VR-based eye-tracking research. For example, otherwise impossible research environments with high ecological validity can be created in VR. However, currently available VR hardware and software may fall short of some vision science paradigms, where extremely well-controlled, high-fidelity stimulus along with precise gaze data recorded with minimum noise are required. Besides its challenges, eye-tracking in VR as a relatively novel yet accessible tool can be adaptive enough for a wide range of research scenarios, and therefore, ways of its inclusion into research might be worth exploring further.

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Symposium 10. Population Receptive Field Modelling: Recent advances and applications

Population receptive fields reveal the neuronal focus of visual attention in non-human primates

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Population receptive field (pRF) modeling is a popular fMRI method to map the retinotopic organization of the human brain. We investigated the neuronal basis of pRFs with whole-brain 3T fMRI and large-scale neurophysiological recordings in awake non-human primates. Analysis of the fMRI BOLD-signal, multi-unit spiking activity (MUA) and local field potential (LFP) power across distinct frequency bands demonstrate retinotopic organization of cortical and subcortical areas and brain-wide sublinear (compressive) spatial summation. Cross-signal analysis confirmed that MRI-based pRFs reliably reflect the neuronal retinotopic organization of the primate brain. In a separate object-based attention experiment, performed by the same animals in the MRI-scanner, pRF information allowed us to use the BOLD-signal to reconstruct not only the visual stimulus but also the spatial profile of selective visual attention from a distinct network of brain areas.

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Early Visual Areas Are Activated During Object Recognition in Emerging Images

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Object recognition in humans happens so quickly that it normally cannot be captured with fMRI. Emerging Images contain a hidden object and extend the process of recognition so it can be studied with fMRI. We used Emerging Images to investigate the involvement of early visual areas (V1, V2 and V3) and lateral occipital complex in object recognition. First, we defined the early visual areas based on retinotopy and the lateral occipital complex using a scrambled images paradigm. Then, during an fMRI scan, we presented the participants (N=8) subsequently with an Emerging Image, the hidden object's silhouette (to aid recognition), and again the same Emerging Image. We compared BOLD responses before and after disambiguation. We used retinotopic parameters to back-project the BOLD response onto the visual field, creating spatially detailed maps of activity change. Additionally, we plotted the activity change as a function of the visual distance to the nearest edge of the object. V1 and V2 - but not V3 or the lateral occipital complex - showed significantly stronger BOLD response after disambiguation than before. The back-projection of cortical activity onto the visual field revealed no specific pattern. Furthermore, there were no activity changes at the object location shown in the distance-to-edge analysis, indicating that the increase in activity in V1 and V2 is not specific for voxels corresponding to the object location. The absence of an effect for the lateral occipital complex may be explained by repetition suppression counteracting the effect of recognition in this object sensitive area.

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Combining pRF mapping and spectroscopy in the healthy and dysfunctional visual system

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Binocular vision underpins our fundamental ability to perceive and act towards a three-dimensional world. In my talk, I will focus on recent insights on the spatial organisation and neurochemical basis of binocular vision.

I will first describe how we used population Receptive Field (pRF) mapping to study neural representations of binocular disparity. By parametrically varying binocular disparity over spatial locations and magnitudes, we found possible specializations for binocular disparity processing in the primary visual cortex and lateral occipital cortex (Alvarez et al., 2021). We also found that disparity preference is not uniformly distributed across visual areas, with an overrepresentation of near and far disparities in higher visual areas (Alvarez et al., in prep). In the second part of my talk, I will describe recent work using Proton MR Spectroscopy to study the neural computations involved in perception. I will highlight links between perceptual processes and neurochemistry in normally sighted participants (Ip et al., 2019; Ip et al., 2021), and mention ongoing work on selective degeneration in the primary visual cortex (Sheldon et al., 2022), as well as abnormal binocular vision in amblyopia. Taken together, our studies suggest that pRF and MRS techniques can yield important novel information about vision. Such research can help inform a detailed mechanistic understanding of the visual brain, an understanding that can build a roadmap for improving healthcare for the visually impaired. Our next step is to study the interplay between cortical metrics and improvements in vision.

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Divisive normalization unifies disparate response signatures throughout the human visual hierarchy

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Neural processing is hypothesized to apply the same mathematical operations in a variety of contexts, implementing so-called canonical neural computations. Divisive normalization (DN) is considered a prime candidate for a canonical computation. Here, we propose a population receptive field (pRF) model based on DN and evaluate it using ultra-high-field functional MRI (fMRI). The DN model parsimoniously captures seemingly disparate response signatures with a single computation, superseding existing pRF models in both performance and biological plausibility. We observe systematic variations in specific DN model parameters across the visual hierarchy and show how they relate to differences in response modulation and visuospatial information integration. The DN model delivers a unifying framework for visuospatial responses throughout the human visual hierarchy and provides insights into its underlying information-encoding computations. These findings extend the role of DN as a canonical computation to neuronal populations throughout the human visual hierarchy.

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Visual timing-tuned responses in human association cortices and response dynamics in early visual cortex

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Quantifying the timing (duration and frequency) of brief visual events is vital to human perception, multisensory integration and action planning. For example, this allows us to follow and interact with the precise timing of speech and sports. Tuned neural responses to visual event timing have been found in areas of human association cortices implicated in visual perception, multisensory integration and action planning. We hypothesized that such event timing representations may be derived from sensory processing areas' neural response dynamics to events, rather than from specialized central pacemakers or processes, as predominant models predict. Therefore, we asked whether and how timing-tuned responses are related to early visual responses, which monotonically increase with event duration and frequency. Participants were presented with repetitive visual events which gradually varied in event duration and/ or period during 7T fMRI. We characterized both monotonic and tuned responses to visual event timing using neural model-based analyses. We found increasingly clear monotonic responses to visual event duration and frequency from primary visual cortex to lateral occipital cortex. From here, we found a gradual transition from monotonic to tuned responses beginning in area MT/ V5. Therefore, across successive stages of visual processing, timing-tuned response components gradually become dominant over the inherent modulation of sensory responses by event timing. This additional timing-tuned response component was independent of retinotopic location. We propose that this hierarchical emergence of timing-tuned responses from sensory processing areas quantifies sensory event timing while abstracting temporal representations from the spatial properties of their inputs.

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Talk session 14. Perception & Action II

Perceptual decision making relies on reducing uncertainty about neural sensory representations

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Fast and accurate decisions are necessary for many adaptive behaviours. In the domain of perceptual decision making, evidence accumulation models postulate that decisions unfold gradually as evidence for different choices accumulates into an abstract decision variable. The content of this decision variable, however, remains poorly characterised. Here we modelled the content of the decision variable by manipulating uncertainty about the properties of sensory input in a speeded motion discrimination task. A group of human observers (N=36) performed the task while their brain activity was recorded using electroencephalography. Behavioural data were modelled using a drift diffusion model and a Bayesian attractor model. The more established and widely used drift diffusion model makes no explicit assumptions about the content of the decision variable, whereas the more recent Bayesian attractor model postulates that the decision variable accumulates uncertainty about sensory representations. Model comparisons revealed that the Bayesian attractor model predicted the observed data better than the drift diffusion model, supporting the notion that in perceptual tasks of the kind we employed, the decision variable represents sensory uncertainty. Using multivariate analyses of observers' brain activity, neural uncertainty was estimated as time-resolved motion tuning to the presented motion stimuli. Using this estimated neural uncertainty instead of simulated uncertainty, a neural Bayesian attractor model was fitted to the behavioural data. Model comparisons revealed that the neural Bayesian attractor predicted the observed data as well as the standard version, suggesting that perceptual decision making relies on reduction of uncertainty about neural sensory representations.

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Sensorimotor anticipation during action observation in real-world and video settings

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Electroencephalography (EEG) studies investigating social cognition have used both video and real-world stimuli. Video stimuli can be selected for practical reasons, while naturalistic real-world stimuli are ecologically valid. The current study investigated modulatory effects on EEG mu (8 – 13 Hz) suppression, directly prior to the onset - and during the course – of observed actions, in either real-world or video settings. Recordings were made over sensorimotor cortex and stimuli in both settings consisted of identical predictable and unpredictable object-related grasping and placing actions. In both settings a very similar mu suppression was found during unfolding of the action, irrespective of predictability. However, mu suppression related to the anticipation of upcoming predictable actions was found exclusively in the real-world setting. Thus, even though the presentation setting does not seem to modulate mu suppression during action observation, it does affect the anticipation-related mu suppression. We discuss the possibility that this may be due to increased social engagement in real-world settings, which in particular affects anticipation. The findings emphasise the importance of using real-world paradigms to bring out the subtle, anticipatory, aspects related to action observation.

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Sensitivity to position and speed in interceptive timing revealed by reverse correlation

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Little is known about the visual precision with which we measure target position and speed in interceptive timing under different temporal constraints of the action. For the first time, we apply reverse correlation to interceptive timing within Virtual Reality (VR) to study sensitivity to position and speed by inferring their psychophysical kernels at the time of interception. People (n=17) pressed a button (keypress condition) or synchronized the end of hand movements (movement condition) when a cloud of approaching dots was aligned with a grid in front of the participants. We added Gaussian noise to the average speed of the cloud so that each dot had a slightly different speed. We recorded the time of the keypress and hand movement onset and offset. After categorizing the responses into early and late categories, we computed the difference of the position and speed noisy distributions between these categories. This difference resembled an edge detection filter and a tuning function for position and speed respectively and were well explained by a kernel based on the difference of two Gaussians with similar means in the case of speed and the SD of the Gaussians reflecting their sensitivity to position or speed. We found higher selectivity for position and speed in the movement condition than in the keypress probably because these variables could be measured at different times during the action.

These results show the benefits of VR in combination with psychophysical techniques to know the visual sensitivity to relevant variables in interceptive timing.

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Grasping complies with Weber's law, when biomechanical factors are not in the way

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When we pick up an object, the variability of our grip aperture does not depend on the variability of the object size, unlike with our perceptual estimates.

The two-visual-systems hypothesis, which assumes separate pathways for action and perception says that Weber's law is violated because the visual coding for the reaching/grasping action is based on absolute metrics.

A different hypothesis says that Weber's law is violated mostly due to biomechanical factors. To contrast these hypotheses, we created a reaching/grasping task where the object size is still a dominant feature, but the biomechanical factors are eliminated.

Our participants (n = 31) had to either grasp and lift rods of different lengths (13, 24, 35 cm, 12x12 mm square profile) with the requirement to achieve a balanced lift (grasping task) or simply indicate the rods' center (perceptual task). We measured the variability of the grasping and indication locations.

According to the two-visual-systems hypothesis, this variability should be the same for all rod lengths for the grasping task, and the variability should increase with the length for the perceptual task.

Instead, we found that the variability increased with object length in both tasks, with identical slopes. Also, the grasping variability did not decrease with repetitions even though both haptic and visual feedback about the object balance was available during lifting.

Our results demonstrate that both grasping actions and perception comply with Weber's law, provided that the biomechanical factors are eliminated.

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Gaze and speech behavior in parent-child interactions: A dual eye-tracking study

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In this study, we used a dual eye-tracking setup to investigate face scanning behavior during video-mediated interactions between parents and their preadolescent children (8-10 years). 81 parent-child dyads engaged in two brief conversations about cooperative and conflictive family topics. We used eye tracking, audio-, and video-recordings to assess what regions of the face are looked at during episodes of speaking and listening, and whether patterns of gaze and speech were influenced by the topic of conversation. Regarding speech, our results show that children spoke more in the cooperation-scenario whereas parents spoke more in the conflict-scenario. Regarding gaze, we found that both parents and children looked more at the other's mouth region while listening compared to while speaking, which converges with previous studies about face scanning during speech perception. Furthermore, we found that parents gazed slightly more at the eyes of their children in the conflict-scenario compared to the cooperation-scenario. Results are discussed in terms of the role that parents and children take during cooperative and conflictive interactions, and how gaze behavior may support and coordinate such interactions.

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Is manual size estimation a valid tool for quantifying size perception?

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Various authors have used manual size estimation as a tool to report perceptual judgments of object size. The effect of visual illusions on such judgments are then compared with the effect on maximum grip aperture in grasping. Is the indicated size indeed a measure of perceived size, or is it a reflection of a planned grasping action? To answer this question, we used prism adaptation of the index finger and thumb in opposite directions (Schot WD, Brenner E, Smeets JBJ (2017) Unusual prism adaptation reveals how grasping is controlled. eLife, 6, e21440). This manipulation changes the grip aperture of grasping movements without changing size perception. In the present study, participants adapted the movements of their unseen index finger and thumb in opposite directions by combining these movements with prisms that deviated in opposite directions. After the adaptation, we removed the prisms, and the participants were asked to indicate the size of two objects, one of 2.3 cm and one of 4.6 cm presented at various locations. They were able to indicate this size difference reliably: their hand opening was 2.4 $\pm$ 0.2 cm (mean $\pm$95% confidence) larger for the larger object. Most importantly, the effect of prism adaptation in indicated size (0.1 $\pm$ 0.2 cm) does not differ from zero and is clearly less than the effect on the grip aperture in grasping (1.2 cm) in our previous study. We conclude

that manual size estimation is a valid tool for quantifying size perception.

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Talk session 15. Adaptation & Aftereffects

Less accurate, but more precise, representations following adaptation to orientation revealed by forward encoding of brain activity in human observers

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Sensory adaptation is a canonical neural function that supports perception and action by facilitating efficient encoding and highlighting salient information. Arguably the most well-known behavioural demonstration of adaptation is the tilt-aftereffect (TAE), whereby prolonged exposure to an orientation alters the perception of subsequently presented nearby orientations. The classic explanation for the TAE proposes that adaptation reduces the responsiveness of neurons tuned to the adapted orientation, which shifts the distribution of population activity elicited by subsequent stimuli. Considerable progress has been made in understanding adaptation; single-cell recordings in animal models and univariate analysis of neuroimaging data from humans supports the neuronal "fatigue" account of adaptation. Despite decades of research, however, empirical evidence demonstrating how population activity representing adapted and nearby orientations is altered in the TAE has yet to be established. Here we applied inverted encoding modelling on patterns of brain activity measured with EEG to show how and when the representation of orientation changes following adaptation. Consistent with previous theoretical work, we present the first empirical demonstration of the fatigue account of population activity. Critically, we also show that adaptation leads to less accurate, but more precise, decoding of the adapted orientation, which provides an explanation for perceptual benefits associated with the phenomenon. Finally, we show that adaptation-related biases in the neural response to stimuli are strongest ~250 ms following stimulus onset and predict corresponding trial-level behavioural biases. These results imply an adaptive mechanism that alters the stimulus representation after the initial feedforward response, consistent with top-down influences.

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Neural mechanisms underlying short-term adaptation in human visual cortex.

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Neurons in visual cortex exhibit reduced responses when stimuli are repeated, referred to as Repetition Suppression (RS). Previous fMRI research has shown that visual regions selective for specific categories show stronger RS for preferred compared to non-preferred stimuli. It remains unclear what neural mechanisms underlie these observed differences in RS. Recent work has shown that many features of the temporal dynamics in human visual cortex, including the degree and recovery of RS, are predicted by a Delayed Normalisation (DN) model. However, this work used simple low-level stimuli and did not account for effects of stimulus category. In order to model and study RS in category-selective visual areas, time-varying broadband data (50-200Hz) was obtained by presenting two identical, naturalistic images with varying inter-stimulus intervals (17-533ms) to patients (n=4) undergoing electrocorticography, yielding robust signals in 102 visual electrodes. We find that for a given electrode, preferred stimuli result in stronger RS than non-preferred stimuli, conforming to findings from fMRI. Second, augmenting the DN model to allow variable input strengths for different stimulus classes enables the model to accurately predict the different RS patterns for preferred and non-preferred stimuli. Third, inspection of the model components shows that the stronger RS for preferred images results from a slower decay of the divisive normalisation and a difference in input drives. Together, this study reveals differences in neural adaptation in category-selective visual areas and offers an approach to study the underlying neural mechanisms which are responsible for the observed dynamical signatures.

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A statistical shape space predicts shape aftereffects in human vision

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Detailed perception of shape is critical in many tasks, including how we recognize and grasp objects. Shape coding is often examined with psychophysical adaptation paradigms that produce perceptual aftereffects. However, it is not clear how these aftereffects arise: Some previous work argues that such aftereffects come from the early stages of visual processing, while other work suggests that they arise from adaptation in a high-level shape space. To determine whether adaptation paradigms tap into high-level shape coding mechanisms, we used data-driven machine-learning methods to synthesize novel shapes in a high-dimensional shape space that captures the way natural shapes (>25,000 animals) tend to vary. In Experiment 1, we find that adaptation to novel shapes produces complex changes in perceived shape consistent with aftereffects along vector trajectories in the statistically-derived shape space. We evaluate several models of low-level visual adaptation, and find that a position-shift aftereffect model, which shifts local line segments on a test shape away from the adaptor, better predicts perceived aftereffects than a tilt aftereffect model, which shifts the orientation of local line segments of the test shape relative to the orientation of the adaptor. In Experiment 2, we directly pit the perceptual aftereffect predictions of the local position-shift model against those of the high-level shape space and show human shape aftereffects go above and beyond local spatial adaptation. Our results suggest that adaptation paradigms tap into higher-level shape coding mechanisms that are in part mediated by the shapes our visual systems evolved/learned to see.

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Facing up to emotional face adaptation: objective measures of the aftereffect are substantially local, and the global component is the same for upright and inverted stimuli

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Adaptation has been used to investigate human face perception, but do the aftereffects have the fidelity and specificity often supposed? We ran three experiments with faces morphed in 31 steps between happy and sad. Experiment-1 used a popular single-interval, binary-choice method for happy/sad judgements and adapters. Repulsive aftereffects (9.8 morph-steps) exceeded the within-observer spread of the neutral-points over a 1-week period (2.6 morph-steps). However, 2.5 hours post-adaptation, repulsion could still be as large as 4.8 morph-steps, suggesting contamination by criterion drift. Rejecting this method, we used spatial 2AFC in Experiment-2, where stimulus pairs were presented each side of a fixation point, happy and sad adapters simultaneously. Observers chose which test-face looked happier and their morph-steps were yoked in opposite directions by a staircase to measure the PSE. To test whether face adaptation aftereffects derive from local (feature) or global (face) processes, we sectorised our stimuli with sixteen radiating wedges creating complementary odd- and even-sector faces (each with half the image content missing) and full-faces. Aftereffects were very similar (~7.7 morph-steps) when spatial configurations were matched across adapter and test (both full, both same-sectors), but only a third of this when adapter and test had complementary sector arrangements. Experiment-3 repeated Experiment-2 using inverted adapt and test stimuli and found surprisingly similar results. We conclude that emotional face adaptation involves local and global components, the most potent being local. That our sector-transfer effect survives inversion implies our global component of face adaptation is not the critical factor in associated face inversion effects.

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The contour erasure effect on contrast discrimination

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After prolong exposure to the contours of objects, these objects can temporally fade from view, a phenomenon known as contour erasure. We examined the underlying mechanism of contour erasure by measuring the contrast discrimination threshold of a target after contour adaptation. The target and pedestal were 1-degree radius disk with various luminance contrasts. The adapters were high-contrast rings of various sizes. On each trial, two contour adapters first appeared on both the upper-right and lower-left quadrants and flickered for 3s at 3Hz, followed by two pedestals at both locations and a superimposed target randomly located at one of the two positions for 83.5ms. The observers were to indicate the target location. We used a Bayesian adaptive staircase to estimate the contrast threshold at 86% accuracy. The target threshold increased after adaptation regardless of the pedestal contrast. The threshold elevation increased with eccentricity and adaptation time but decreased with stimulus-onset asynchrony. The threshold showed an adapter size tuning, peaking when the adapter radius was about 0.7 target radius. We fitted the data with a divisive inhibition model, where the stimulus response is calculated by an excitatory component raised by a power and divided by an inhibitory component plus a normalizing constant. The adaptation effect is captured by changes in the sensitivity parameters and normalizing constant. Our study is the first to investigate the contour erasure effect quantitatively with a threshold measurement and showed that it is a function of stimulus

properties such as luminance contrast, eccentricity, and adapter size.

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Talk session 16. Clinical Aspects & Clinical Populations

The speed acuity test as a new tool for the assessment of visual development and cerebral visual impairment

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Visual task performance is generally characterized by speed-accuracy trade-offs, suggesting that it is important to measure both speed and accuracy to better assess visual impairments. Currently, however, the diagnosis of visual impairment is based mainly on perimetry and non-timed visual acuity tests. Recently, we therefore developed a discrimination reaction-time test in which participants indicate the orientation of Landolt-C symbols as quickly and accurately as possible, to determine how quickly participants can discern visual details. This speed acuity test determines both the accuracy and the latency of the responses to different optotype sizes. Analysis of data collected from 5- to 12-year-old children with a drift-diffusion model revealed substantial developmental improvements in visual discrimination speed. This suggests an important optimization takes place in the developing visual system. In addition, we found that children with cereberal visual impairments (CVI) need significantly more time to respond to the largest optotype sizes than age-matched normally sighted (NS) children and children with visual impairments due to an ocular disorder (VIo). This effect is independent of the time it takes to make a motor response. However, the reaction-time difference between the children with CVI and VIo is not seen for optotype sizes at the acuity threshold. Our findings thus indicate that the difference in reaction time between CVI and NS is an important outcome for the clinical diagnosis CVI.

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Assessing visual emotional intelligence with Inferential emotion tracking (IET)

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Visual perception of facial features or expressions is a primary component of nearly all proposed metrics of emotional intelligence. However, emotion can be recognized consistently and accurately entirely based on contextual information, even in the absence of faces or facial expressions. Context may therefore be an important factor to include in measures of emotional intelligence. A recently developed technique to isolate and measure the role of context in emotion perception is inferential emotion tracking (IET; Chen & Whitney, PNAS, 2019). The method requires observers to track and continuously report, in real-time, the emotion of invisible characters in natural movies. The approach is effective for tracking either categorical emotion or affective state (Chen & Whitney, Emotion, 2020). Using IET, we have demonstrated that context provides accurate information about emotion with the same latency as facial expressions (Chen & Whitney, Cognition, 2021). Here, we explore whether IET might be useful as a metric of visual emotional intelligence. As a testbed, we examined whether there are consistent individual differences in IET ability and whether these can serve as diagnostic markers of neurodevelopmental disorders including autism. We found that individuals vary in their ability to infer emotion from context and this ability correlates significantly with self-reported measures of Autism including the Autism Quotient (AQ). Because IET was able to capture and explain individual differences better than other assessments (e.g., questionnaires) and visual tasks (e.g., face and eye recognition tasks), it may be a useful component in general measures of emotional intelligence.

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Investigating the relationship between alpha oscillations frequency and visual temporal segregation in dyslexia and neurotypical controls

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One essential property of perception is the ability to integrate sensory information over time to form meaningful objects, as well as segmenting visual input to unveil changes in the environment. These complementary components of temporal processing have been proposed to have a key role in reading and in developmental dyslexia, with recent evidence confirming a specific deficit in dyslexia in segmenting visual stimuli, despite

unaffected temporal integration abilities. However, little is known about the underlying neurophysiological anomalies. Here, we recorded EEG while dyslexics (N=26) and controls (N=31) performed a task that measures temporal integration and segregation by presenting two sets of stimuli separated by a varying temporal interval. Performance on this temporal processing task was investigated in relationship with the speed of endogenous alpha oscillations (i.e. individual alpha frequency), measured during a resting state period. We replicated the deficit in rapid visual segmentation in dyslexia, which was linked to differences in the neural event-related responses. Moreover, results showed that control participants with slower resting-state alpha oscillations exhibited better temporal segregation abilities. Notably, this relationship between alpha speed and segregation performance was absent in dyslexics, which showed a positive correlation between resting-state alpha and integration performance. Our findings challenge the idea, based on previous studies using flickering flashes rather than the more complex stimuli employed here, that faster endogenous alpha oscillations predict faster temporal resolution in the neurotypical population. They also provide new evidence about the neural correlates of rapid visual segmentation deficits in dyslexia that are potentially useful for intervention.

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Crowding disrupts colour and motion perception independently in development and amblyopia

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Crowding is the disruption to object recognition in clutter. In peripheral vision, crowding has recently been found to disrupt colour and motion perception independently, operating as a feature-specific (not object-specific) process. Though crowding is typically minimal in foveal/central vision, elevations occur during development and with amblyopia, a developmental visual disorder. Are these elevations the same for all feature dimensions? We examined the spatial extent of crowding for colour and motion in the developing and amblyopic fovea. Children aged 3-9 years with typical vision (n=32) or strabismic amblyopia (n=24) were shown a foveal 'cowhide' target and judged its direction (left/right of upwards) or hue (blue/green). Targets were in isolation or surrounded by 6 flankers, with stimulus sizes (and proportional inter-element spacing) varied using QUEST.

On average, typically-developing children showed similar size-acuity thresholds for colour and motion with isolated targets. Thresholds were elevated in the presence of flankers, and to a greater extent for motion than colour, particularly for children below 6 years of age. For children with amblyopia, colour thresholds were elevated monocularly: performance was similar to typical children in the fellow/unaffected eye, with elevations in the amblyopic eye for isolated targets and further elevation when crowded. In contrast, motion deficits were binocular. In the fellow eye, thresholds were elevated for isolated targets, with further elevations when crowded. Additional elevations occurred in the amblyopic eye, with crowded motion judgements extremely disrupted. These distinct patterns of elevation suggest that crowding disrupts vision in a feature-specific manner in both typical and amblyopic development.

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Spectral EEG power in response to visual social information as an endophenotype of Autism

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Background: Spectral EEG power has been suggested as an endophenotype of Autism Spectrum Disorder (ASD) during infancy, mostly by studies in which a researcher blew bubbles to hold the infants' attention during recording. Although valuable, these studies conflate processing of visual social (the researcher) and non-social (the bubbles) stimuli. The current study extended previous designs therefore, by comparing EEG responses to social versus non-social videos, shown sequentially. This allows us to move from global group differences to examining differences in specialized neural networks, and the within-subjects design allows us to control for influences of physical differences such as scalp thickness. Methods: We included 85 infants at elevated likelihood for ASD and 31 at low likelihood for ASD, at 10 and 14 months of age. EEG was recorded while infants viewed social (women singing nursery rhymes) and nonsocial videos (toys moving with accompanying sound). Results: Analyses on frontal electrodes revealed that power in the alpha band was higher in the elevated compared to the low likelihood group at 14 but not 10 months, but this did not depend on the type of video. Furthermore, cluster-based permutation tests on all electrodes revealed group differences for

the social but not non-social videos in the delta, alpha, and beta bands. Discussion: The results confirm that differences in spectral EEG power in response to visual information, particularly in the alpha band, might be an endophenotype of ASD. Furthermore, they suggest that this group difference might be specific for social visual information when investigating whole-brain activity.

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Saccadic compression of space and time in children with and without reading impairment

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Saccades have always been considered a key component of reading skills and, unsurprisingly, saccades abnormalities characterize eye movements in dyslexic individuals. Nonetheless, saccades alone are seldom explanatory of an individual's reading abilities and are barely informative for clinicians, which refer to semantic evaluations to diagnose dyslexia. Moreover, saccades also induce profound changes in visual perception, such as transient compressions of spatial and temporal information, which have been explained by the predictive anticipatory remapping along the visual pathway and the general involvement of the magnocellular stream. Given the strong interconnection between magnocellular pathophysiology and dyslexia, we thereby hypothesize that those who are dyslexic should experience different patterns of saccades-induced perceptual distortions. Displaying briefly flashed stimuli around saccadic onset, we thereby tested both spatial and temporal perception within the peri-saccadic timeframe in both dyslexic and normal reading children. Our results highlighted that dyslexic children exhibit a significant reduction of saccadic compressions compared to normal-reading peers, resulting in reduced perceptual distortions for both spatial and temporal judgments. Interestingly, our results suggest that both compression measurements could be successfully combined to classify children as either dyslexic or not, maintaining high degrees of specificity and sensitivity. With the current work, we bring evidence that reduced saccadic compressions characterize dyslexics' vision, raising for the first time the potential role of impaired predictive anticipatory remapping mechanisms. Thus we provide a theoretical foundation for a non-semantic assessment of dyslexia, that relies on a purely perceptual task and that can potentially foster early diagnosis and intervention for children.

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Talk session 17. Scene Perception

Representational hierarchy in human and artificial visual systems in the presence of object-scene regularities

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Human vision is still largely unexplained. Computer vision made impressive progress on this front, but it is still unclear to which extent artificial neural networks approximate human object vision at the behavioural and neural levels. Here, we investigated whether machine object vision mimics the representational hierarchy of human object vision with an experimental design that allows testing within domain representations for animals and scenes, as well as across domain representations reflecting their real-world contextual regularities such as animal-scene pairs that often co-occur in the visual environment. Our findings highlight surprising similarities but also differences between the two systems. DCNNs trained in object recognition acquire representations, in their late processing stage, that closely capture human conceptual judgements about the co-occurrence of animals and their typical scenes. Likewise, the DCNNs representational hierarchy shows surprising similarities with the representational transformations emerging in domain-specific ventral-temporal areas up to domain-general frontoparietal areas. Despite these remarkable similarities, the underlying information processing differs. The ability of neural networks to learn a human-like high-level conceptual representation of object-scene co-occurrence depends upon the amount of object-scene co-occurrence present in the image set thus highlighting the fundamental role of training history. Further, although mid/high-level DCNN layers represent the category division for animals and scenes as observed in the ventral pathway, its information content shows reduced domain-specific representational richness. To conclude, by testing within- and between-domain selectivity while manipulating contextual regularities we reveal unknown similarities but also differences in the information processing strategies employed by human and artificial visual systems.

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The Visual Canvas

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Visual information processing uses visual contrast, because the receptive fields of ganglion cells (or LGN cells) with difference-of-Gaussian (DOG) structure remove the mean luminance to a large extent. Correspondingly, models of visual processing consist of increasingly complex arrangements of units with essentially only a sensitivity to local spatial derivatives of the light field. However, one cannot conclude that the luminance field is inaccessible beyond the retina. Image reconstruction from appropriate arrangements of multi-scale DOG signals up to three global image parameters is possible in principle. That reconstruction can be re-sampled with a set of Gaussian derivatives sharing locus and blur-scale to form a Taylor approximation set (TA), that characterises the surrounding blurred lightfield. At their borders, neighbouring TAs cross-calibrate. Thus a grid of such local-texture identifiers together form a visual canvas on which the retina "projects" the image information. The canvas allows e.g. scene discrimination in a very noise-robust way reproducing human discrimination between natural and man-made images(1). Also, combining the TA with eye position signals the canvas can stabilize its output against eye displacements up to the blur-scale (2). Hence, the canvas could provide a stable backdrop against eye movements (< 15 deg) when built at an eccentricity independent blur-scale of about 20 deg, as found in a scene-processing related, anterior-occipital area V2A (3) .

1:Geuzebroek AC et al. (2018) JOV 18(9).
2:Beintema JA et al. (1998) Vision Res 38 p 2155.
3:Elshout et al. (2018) JOV 18(9).

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Boundary extension depends on prior visual experience

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Boundary extension (BE) is a classical memory illusion in which observers remember more of a scene than was presented. This illusion has been linked to predictive mechanisms, by which observers' memory is supplemented by expectations of what is beyond a scene's boundaries. Alternative accounts have explained BE in terms of more generic normalization mechanisms, or by low-level image completion. Here, we manipulated prior visual experience to provide a direct test of predictive contributions to BE. Participants (N=85) were exposed to videos of outdoor environments, with the camera moving left-to-right or right-to-left. After exposure, they completed a view-change detection task on screenshots coming from those videos. Each trial showed two versions of the scene, with one of the two slightly zoomed in compared to the other. Participants had to indicate whether the second view was closer or farther than the first. Crucially, we manipulated the view-changes such that these impacted only the boundary congruent or incongruent with the previously experienced direction of the video. As predicted, boundary extension occurred only when view-changes involved the boundary congruent to the video direction, such that participants expanded the boundaries in the direction in which they had previously viewed the scene. These results support predictive accounts for the boundary extension illusion. More generally, they support views of scene perception as a constructive process, integrating the visual input with the observers' expectations based on prior experience.

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Cortical encoding of spatial structure and semantic content in 3D natural scenes: an MEG study

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What are the cortical processing stages that underlie our ability to effortlessly understand and navigate real-world visual environments? Functional magnetic resonance imaging studies suggest a network of scene-responsive cortical visual areas (such as OPA and PPA), but the temporal processing stages remain incompletely understood. Here we selected a set of 36 full-color natural scenes that varied in spatial structure and semantic content. Twenty subjects viewed the same scenes both monoscopically (2D) and stereoscopically (3D) while we recorded magnetoencephalography (MEG) data. We compared the representational geometry in the MEG responses with predictions based on the scene stimuli using the representational similarity analysis framework. The representational geometry first reflected the spatial structure in the scenes, followed by the semantic content. Stereoscopic viewing affected the responses relatively late. Taken together, our results support the conclusion that the human visual system rapidly encodes a scene's spatial structure and suggest that this information is based on monocular instead of binocular depth cues.

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Who to whom? Encoding thematic roles in social scenes is rooted in visual perception

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Recent research shows that, in multiple-person scenarios, visual perception encodes information about single bodies as well as information about their relative positioning, which provides a reliable cue with respect to whether two bodies are interacting (e.g., face-to-face) or not (e.g. back-to-back). Here, we asked whether perception uses visuo-spatial information (body posture and/or relative positioning) to encode the thematic roles of the participants in a social interaction –i.e. who is the agent and who is the patient.

In 10 experiments using a switch cost paradigm, participants saw displays of body dyads and indicated the side (left/right) of a target individual (male/female). From one trial to the next, the role of the target could change. Participants were slower in identifying the location of the target when the role of the individual changed, relative to when it did not change, showing that the individuals' roles were automatically and implicitly processed, influencing the primary visual task.

In addition, we found a hierarchy in the cues that participants used to assign the roles. Participants relied on the relative positioning: the agent is the body in the spatial position that allows acting upon the other (the patient). When the relative positioning did not allow distinguishing between agent and patient (e.g. bodies are back-to-back or face-to-face), participants relied on the postures being more or less agent-like (e.g., leaning forward).

Altogether, these results suggest that the identification of thematic roles, such as agent and patient, that structure semantic representations of actions and interactions, are rooted in visual perception.

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The central shadow rules them all: About how we assess the main location of light source via analysis of drop shadows in a scene

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How does a visual system combine conflicting visual cues to estimate the relative position of a light source for a scene? We investigated this by asking participants (N=27) to estimate an average direction of shadows in a scene that contained nine Playmobil toy figures placed on a 3×3 grid, photographed from a bird's view (17° altitude, from a ¾-view, ~24° deviated from frontal). We manipulated the number of shadow directions (11 steps of 32.7°) within the scene, ranging from all nine shadows pointing to the same direction to only five "majority" and four randomly oriented distractor shadows. Additionally, we created a control condition with the same shadow images lacing the toy figures to test the effects for shadow-specific processing (2×451 trials per participant). First, we analyzed what scene information participants use when computing an average estimate by devising nine ideal observer models with different weighting schemes, fitting them via a Bayesian sampling approach, and comparing via leave-one-out information criterion. The best estimate was an average weighted by the figure's eccentricity and shadow's length. Yet, the weights were so extreme that participants' estimates primarily reflected the central shadow's orientation with other figures being largely ignored. However, the context did influence the perception decision as the presence of conflicting shadows significantly increased the variability of responses. The same was observed for response times with slower responses for stronger conflicts in the scene. In short, although the perceptual decision about shadow orientation depends only on the central figure, it is modulated by context.

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Talk session 18. Motion Perception

Unsupervised predictive learning gives rise to V1- and MT-like motion tuning

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A hierarchy of motion-tuned cells allows us to perceive the speed and direction of objects in the world by combining ambiguous local motion signals. These motion computations must develop without access to ground truth information about object motion. Here we tested whether an ecologically feasible learning objective—unsupervised learning by predicting future observations—could yield cortex-like motion processing. We trained a two-layer recurrent convolutional network based on predictive coding principles (PredNet) to predict the next frame in videos. Training stimuli were 64,000 six-frame videos of natural image fragments sliding with uniformly-sampled random speed and direction. The network was trained to minimise mean absolute pixel error between its prediction and the next frame. We found that, despite receiving no explicit information about

direction, most units in both layers of the network showed tuning to a specific motion direction when probed with sliding sinusoidal gratings. Many developed a preference for a specific combination of direction, speed, and spatial frequency. Like MT neurons, units in the network appeared to solve the "aperture problem", when probed using pairs of orthogonally-drifting gratings superimposed to create plaid patterns. Around half the units in the second layer, and fewer in the first layer, were tuned to the combined direction of the whole pattern, rather than to the directions of its individual components. Unsupervised predictive learning can give rise to cortex-like single unit tuning and integration of locally-ambiguous motion signals, providing an interrogable model of how motion processing develops.

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Rotating objects cue spatial attention via the perception of frictive surface contact

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One of the most important functions of visual processing is to predict how objects will move, in order to orient attention to where they will be next. For example, if we see a car start to spin its wheels in the mud, it behooves us to form a prediction about where it will move next, in order to attend there. Here we report that rotational motion drives spatial orienting in a manner consistent with a specific physical assumption—that objects are generally in frictive contact with a surface beneath them. In Experiments 1 and 2, observers viewed displays in which a 'pinwheel' appeared in the center and rotated clockwise or counterclockwise. A letter appeared on its left or right, and subjects responded as quickly as possible to identify the letter. This revealed a powerful cueing effect: clockwise rotation produced faster responses to letters on the right, and counterclockwise rotation produced faster responses to letters on the left. This pattern of spatial orienting is sensible for objects making frictive contact with a surface below, but should reverse for objects shown touching a 'ceiling'. In Experiments 3 and 4, rotating pinwheels were shown touching a horizontal line either below or above. Pinwheels contacting 'floors' produced a qualitatively identical cueing effect; pinwheels contacting 'ceilings' produced a reversed cueing effect. Thus, rotational motion drives spatial orienting in a manner based on both (1) past experience seeing objects move in a terrestrial environment, and (2) a sophisticated model of physical forces in the current situation.

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Position representations of moving objects align with real-time position in early visual cortex

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When localising a moving object, the brain receives outdated sensory information about its position, due to the time required for neural transmission and processing. It has been suggested that these fundamental delays are overcome through predictively encoding the position of moving objects using information from their past trajectories. In the present study, we address this proposition using multivariate analysis of high temporal resolution electroencephalographic data. We track neural position representations of moving objects at different stages of processing, relative to the real-time position of the object in the world. To achieve this, we presented a stimulus that was either briefly flashed in one position or moving smoothly along a straight trajectory passing through the flash positions. We used classifiers to identify neural representations of the position of flashed stimuli at a range of timepoints relative to stimulus onset. We then established the latencies at which these position representations occur in the case of flashed and moving stimuli. We found that, during early stimulus-related activity (100-160ms), the activations of position representations of moving objects are shifted substantially earlier than the equivalent activity evoked by unpredictable flashes. This shift was sufficient to bring the early representations (~100ms) of the moving object into alignment with its real-time position. Our findings indicate that position representations are already shifted in the early stages of the visual evoked response, and that delays still accumulate across subsequent stages of cortical processing.

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The double ring illusion: Object solidity is used to disambiguate ambiguous motion

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Is the basic physical law of "solidity" – solid objects cannot traverse each other – embedded in automatic perceptual processes? We discovered a visual illusion showing that the visual system uses solidity to interpret ambiguous motion. When two bistable rotating rings (that create a percept alternating between 180 ° and 360° rotations) partially overlap, they appear to move in stable 180° rotations – thus "avoiding" solidity violations. However, if one of the overlapping rings is gapped such that the other can pass through, the unstable percept is restored (demo: https://osf.io/zm8dx/wiki/home/?view_only=658452ac87324473addcbc298e590d82). Experiment 1 confirmed this illusion. Participants saw separated, overlapping or gapped rings, and indicated what they saw by choosing from two unambiguous rings moving in 180° or 360° rotations. We compared the rates of 180° responses. Participants responded at chance with separated rings (50.4%), while preferring 180° rotation with overlapping rings (73.9%) and less so with gapped rings (68.4%). Experiment 2 investigated how shadows influence such percept. Shadows moving in 180° or 360° rotations were added underneath overlapping or separated ambiguous rings. Results showed that 180° shadows increased the 180° response rate (compared to without shadows) less for overlapping rings than for separated rings, whereas 360° shadows decreased the 180° response rate equally in both types of rings (nevertheless, participants responded 180° more with overlapping than with separated rings). Together, these results suggest that solidity guides the interpretation of ambiguous motion. The 180° percept created by overlapping rings is near ceiling and cannot be completely overridden by contradicting shadow cues.

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Cross-Orientation Inhibition measured through Continuous Tracking

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Cross-orientation inhibition describes the reduction in response gain of visual cortical neurons to an oriented stimulus (target) by a second stimulus of different orientation (mask), which alone would evoke no response in that neuron. This effect has been explained in terms of gain-control mechanisms, where neurons selective to the mask inhibit the response of neurons selective to the target. This effect has been difficult to measure psychophysically, as it tends to manifest itself most clearly at contrasts above threshold.

We employed continuous tracking, a new psychophysical technique, to study this phenomenon: participants viewed a moving vertical Gaussian bar, superimposed on various pedestals: a gray background or a series of stripes with randomly distributed luminance values, oriented at 90 or 80 degrees with respect to the bar. Cross correlating the velocity of the stimulus with cursor movements provides useful information about perception, from the peaks and lags of the cross-correlograms.

The results showed that performance is reduced by oriented backgrounds, that can be well characterized by the action of gain-control mechanisms, which reduce response gain and increase reaction times. This study is one of the few psychophysical studies characterizing cross-orientation inhibition and gain control.

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Improved time-to-collision estimates for accelerating objects: The effect of a visual acceleration signal

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When estimating how long a visually displayed accelerated object takes to arrive at a given position (time-to-collision, TTC), humans commit significant estimation errors. In numerous studies, TTC estimates for such objects showed a distinct first-order pattern, suggesting that acceleration was not adequately accounted for in the estimation process. We investigated whether a simple visual signal indicating the acceleration state can reduce these estimation errors. In a traffic simulation showing the perspective of a pedestrian standing at the curb, twenty-six participants estimated the TTC of vehicles that approached with constant velocity or accelerated positively. In half of the experimental blocks, a light band on the windshield illuminated whenever the vehicle accelerated but remained deactivated at constant speeds. In the other blocks, the light band was never illuminated. Participants were informed about the light band function in each block. Without acceleration signal, the TTC estimates showed the expected first-order pattern and thus large estimation errors. However, when the vehicle's acceleration was indicated by the light band, the first-order pattern was significantly reduced, and TTC estimates were significantly more accurate compared to conditions without acceleration signal. At constant velocities, participants underestimated the TTC on average. Overall, a visual acceleration signal can significantly attenuate the first-order pattern for visually presented accelerating objects by promoting the consideration of acceleration.

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Poster session 19. Face Perception - II

Ingroup and outgroup differences in face detection

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Humans show improved recognition for faces from their own social group relative to faces from another social group. Yet before faces can be recognised, they must first be detected in the visual field. The current experiments investigated whether humans also show an ingroup bias at the earliest stage of face processing – the point at which the presence of a face is first detected. To this end, observers' detection performance was measured for ingroup (Black, White) and outgroup faces (Asian, Black, White) embedded in everyday scenes. In Experiment 1, ingroup faces were detected with greater speed and accuracy relative to outgroup faces. In Experiment 2, removing face hue impaired detection generally, but the ingroup detection advantage was undiminished. This same pattern was replicated by a detection algorithm in Experiment 3 using face templates derived from human data. Collectively, these findings demonstrate that the established ingroup bias in face processing can extend to the early process of detection. This effect is 'colour blind', in the sense that group membership effects are independent of general effects of image hue. Moreover, it can be captured by tuning visual templates to reflect the statistics of observers' social experience. Group bias in face detection is therefore both a visual and a social phenomenon.

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Time-resolved decoding of human face emotion processing from multivariate EEG data

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esearch on electrophysiological correlates of human face processing has often focused on the timing and amplitude of event-related potential peaks. Here we use time-resolved MVPA of EEG data to study the neural information associated with face processing across a trial. We find effects of face inversion at the earliest stages of visual processing and correlates of emotion processing later in the visual processing hierarchy. Surprisingly, we also find some evidence for early, possibly subcortical processing of emotional valence information.

640 images were extracted from face image databases and presented to subjects (N=40) in a jittered, randomised event-related design (stim duration 200ms, mean ISI=2s). Low-level visual features were normalised across images (SHINE toolbox) and images were Gaussian windowed to reduce edge artefacts. Subjects indicated perceived emotion (happy, angry, fear, neutral) with a keypress. EEG data were recorded using a 64ch ANT and decoded across time in 5ms intervals using a support vector machine (SVM).

Behaviour: We found a significant recognition performance on all emotion classes and a significant effect of inversion. EEG: Group-level multivariate decoding of upright vs inverted faces occurred after approximately 80ms and decoding of facial emotion was reliable from 280ms after stimulus onset. A brief burst of significance for decoding negative-valenced emotion occurred around 110ms.

Parsing face emotion may require the parsing of subtle configural and featural changes that occur in later 'face-specialised' areas but some information relating to emotional valence may be computed early in the visual pathway.

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Multiple Face Detection

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In social environments, we often encounter several faces at once. Although strict capacity limits (one face at a time) have been reported for later stages of face processing, e. g., identification, it is not clear whether this bottleneck precedes or follows the initial detection step. In a series of behavioural experiments, we investigated efficiency of multiple face detection by embedding 1–4 target items (all upright faces, all inverted faces, or all phase-scrambled faces) in complex scenes. For each scene, participants reported the number of targets by pressing the appropriate response key (1–4) as quickly and accurately as possible. In Experiments 1 & 2, we tested performance using different presentation times (250 ms in Experiment 1; until response in Experiment 2). In Experiments 3 & 4 we presented different levels of scene complexity (blank backgrounds in Experiment 3; Voronoi-filtered scenes in Experiment 4). Across all these experiments, we found no per-item cost for upright or inverted faces. Performance was especially efficient for upright faces. In Experiments 5 & 6, we presented 90° 'sideways' faces as targets to assess the importance of left-right symmetry and horizontal eye-pairs. Performance was more efficient for upright faces than for sideways faces, suggesting a possible role for axes of symmetry. Parallel face detection is highly efficient, at least up

to four items, even in complex scenes. Face detection is not subject to strict capacity limits that mandate one face at a time suggesting the bottleneck in face processing occurs after the detection step.

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No influence of color and contrast on Flashed Face Distortion Effect

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When a series of faces are rapidly presented to peripheral vision, observers feel strong uncanniness and distortion of the faces (Flashed Face Distortion Effect; FFDE, Tangen et al., 2011). Color perception could contribute to the emergence of FFDE since previous studies reported that the color of faces appeared to change during experiencing FFDE. However, the local contrast of faces manipulated by adding/removing makeup had little influence on FFDE. The present study examined the influence of color and contrast on FFDE by manipulating the color and contrast of whole images of faces. For this purpose, we used colored and grayscale pictures with high, normal, and low contrast. The participants, observing a series of pictures presented at 4 Hz for 10 seconds in the peripheral vision, were asked to press a key while they felt the distortion of faces to measure the latency and cumulative duration of FFDE. After the stimulus presentation, the participants were also asked to evaluate the strength of subjectively perceived uncanniness and distortion on a 7-point scale. The result demonstrated that both temporal characteristics and subjective rating were almost constant among stimulus conditions, which implied that the color and contrast had no significant influence on FFDE. Taken together with the previous studies, the variation of physical color and contrast among the sequence of facial pictures would not contribute to the emergence of FFDE. Further study is necessary to reveal the underpinning process of distortion of color appearance during experiencing FFDE.

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Impaired detection of mismatches in color incongruent image pairs is immune to interventions.

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The role of image color in face image comparison has received little attention in research despite the photographic ID documents remaining the most common way of identity verification. Previous research by our group suggests mismatched pairs of images where one is displayed in color and one in monochrome (incongruent) are detected less accurately than mismatched pairs with two color or two monochrome photographs. Here, in four experiments, we investigated whether we can eliminate the low mismatch detection rate in incongruent image pairs. In each experiment, participants were presented pairs of images from the Models Face Matching Test and asked to decide whether they show the same person or two different people. The photographs were either both color, both monochrome, or color incongruent. We blocked the color conditions (Experiment 1), informed the participants about the low detection rate in mixed condition (experiment 2), attempted to interrupt the pattern of responding via mini-tasks throughout the experiment (experiment 3), gave participants feature-based instructions reported to improve face matching (experiment 4). Despite these interventions, the detection rate in color incongruent pairs remained low relative to color and monochrome pairs. The results further show that "environmental" differences (photograph color) can reduce detection of mismatched pairs. Given that some photographic IDs are still monochrome (e.g., Polish national ID card) and people carrying them are in real-life color scheme, this incongruency can have a seriously negative impact on detecting cases of fraudulent ID bearing.

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Masks can't cover up your anger: to investigate the influence of the frequency of social interaction on emotion recognition

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As COVID-19 is continuing to grow, it forces people to wear masks in daily life, which disturbs facial expression recognition, an important ability for social communication. Further, previous studies showed that the sensitivity to subtle differences in facial expressions could be trained through social experience. Therefore, we aimed to investigate whether people with different social experiences would affect their emotion recognition. We hypothesize interpersonal experience would compensate for the difficulty of emotion recognition resulting from partial occlusion of masks. In Experiment 1, all participants were separated into high and low social frequency (HSF/LSF)

groups using a questionnaire about the frequency of social interaction. For controlling the task difficulty, we manipulated the intensities and types of facial expressions to find out the near-threshold intensities for being the stimuli of Experiment 2. In Experiment 2, both groups participated in the Emotion Discrimination Tasks and they were asked to discriminate the presented faces as positive or negative. The stimuli were a whole face (Experiment 2A) and a half face to mimic the wearing mask condition (Experiment 2B). The result showed that the participants responded significantly more accurately to the whole face expressions than did to half-faces, which implied the occlusion of masks would disturb emotion recognition. Compared to the LSF group, the HSF would respond to negative emotions significantly more accurately in both whole and half-faced stimuli, revealing that social experience affected facial expression recognition. We concluded the social experience would impact the facial expression recognition.

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Facial expressions reflect your mental situation

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Currently, we have more opportunities to use video calling systems, instead of communication in person. Furthermore, the population of patients with depression has been increasing since the covid pandemic began. Many past studies suggested both verbal and non-verbal information as criteria to detect mental problems. Especially, facial-expression is one of the richest data to explain emotions. Our main goal is developing system to detect the early stage of depression using non-verbal information. We will report the result compared facial expressions between control and depression symptoms groups while participants were talking to a virtual avatar in the non-clinical interviews. In the experiment, participants were asked to communicate with a virtual avatar. Meanwhile, facial expressions were recorded using a web camera. Then, we computed statistical data and demonstrated the result classified participants as with or without depression using machine learning based mathematical modeling. As for the result, facial expressions are possible to be one of the criteria to classify people as being with or without depression. This research was supported by European Regional Development Fund (ERDF) for Post-doc projects grant agreement No 1.1.1.2/VIAA/4/20/668

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Introducing the Cambridge Face Memory Test – Malaysian Chinese (CFMT-MY)

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The Cambridge Face Memory Test (CFMT) is one of the most prominent measures of face recognition ability used in face recognition research. Because of the well-known existence of the other-race effect whereby individuals show superior recognition for own-ethnicity faces compared to other-ethnicity faces, we developed a novel version of the Asian CFMT – the Cambridge Face Memory Test – Malaysian Chinese (CFMT-MY). In Experiment 1, we tested 132 Malaysian Chinese participants in two versions of the Asian CFMT (CFMT-China, and CFMT-MY) and one car recognition test; in Experiment 2, we asked 135 Caucasian participants to complete these two versions of CFMT along with a third: CFMT-US. Results revealed that the CFMT-MY is a valid measure of unfamiliar face recognition, with both high internal reliability score and high construct validity. Malaysian Chinese participants scored higher in the CFMT-MY than in the CFMT-China, particularly under the difficult condition which included lighting changes and visual noise. Caucasian participants showed their best performance in the CFMT-US across all difficulty levels, followed by the CFMT-MY and then the CFMT-China. Overall, the CFMT-MY is a suitable test for the diagnosis of face recognition difficulty and could be used as a standardized measure by researchers who wish to examine individual differences in unfamiliar face recognition and/or the other-race effect.

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Investigating the role of the occipital face area (OFA) and fusiform face area (FFA) using multifocal transcranial direct current stimulation (tDCS)

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The functional role of the occipital face area (OFA) and the fusiform face area (FFA) in face recognition is inconclusive to date. While some research has shown that the OFA and FFA are involved in early (i.e., featural processing) and late (i.e., holistic processing) stages of face recognition respectively, other research suggests that both regions are involved in both early and late stages of face recognition. Thus, the current study aims to further examine the role of OFA and FFA using multifocal transcranial direct current stimulation (tDCS). In Experiment 1, 35 participants completed whole faces and independent facial features (i.e., eyes, nose, mouth) recognition tasks after OFA/FFA stimulation using a within-subject design. No difference was found in recognition performance after FFA and OFA stimulation. Experiment 2 included a control (sham stimulation) group and stimulation was implemented using a between-subjects design with 60 participants. Results showed that FFA stimulation led to enhanced efficiency and quicker recognition of independent facial features, however, no effect of OFA stimulation was found. These results suggest the involvement of FFA in the recognition of independent facial features in the early stage of face recognition.

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Knowledge-Augmented Face Perception in Humans and Synthetic Systems

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Human visual perception is efficient, flexible and context-sensitive: For instance, knowledge about a person's past social behavior can make us perceive emotional expressions in neutral faces. Psychologists often explain such effects with the Bayesian brain view, according to which probabilistic perceptual inference integrates prior experience and knowledge through top-down influences. Recent advances in machine learning, such as more powerful Artificial Neural Networks (ANNs), have enabled considerable progress in computer vision. However, in contrast to human perception, neural networks do not typically take top-down information like prior knowledge or context into account during online processing. To help close this gap, we identify key characteristics of knowledge-augmented and context-sensitive face perception in humans in order to leverage such sources of information in computer vision. We propose that both fields engage in an epistemic loop: Integrating top-down processing into synthetic systems could make networks more flexible and useful for human-machine interaction. In turn, employing ANNs as scientific tools will widen the scope of empirical research into human knowledge-augmented perception. We apply this approach to test whether ANNs can align with flexible, context-sensitive human perception: using the reverse correlation technique, we train ANNs to approximate and visualise human mental representations of facial expressions seen in the context of positive or negative person-related prior knowledge.

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Acuity for face recognition is better in the lower versus the upper visual field

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Low-level vision varies predictably across the visual field, with abilities like acuity better along the horizontal vs. vertical meridian and in the lower vs. upper visual field. In contrast, variations in face perception have been reported to be idiosyncratic. Because face perception is typically measured using judgements of appearance for faces of the same size, we sought to bridge the gap in methodology used in low- and high-level vision with an acuity test for face recognition. Previously, we demonstrated that acuity for face recognition was better along the horizontal vs. vertical meridian. However, the upper-lower difference was smaller in magnitude and significant in only one of two experiments. In this experiment we addressed the upper-lower difference directly, by focusing on those locations only and increasing the number of trials. We presented upright and inverted faces in the upper and lower visual field, at 10° eccentricity. Face size varied via an adaptive QUEST procedure, allowing us to measure the smallest size necessary to judge gender at each location. For both upright and inverted faces, thresholds were larger in the upper than the lower field, indicating that faces needed to be larger in the upper field to achieve the same accuracy. This demonstrates that acuity for face recognition is indeed better in the lower vs. upper field, revealing another anisotropy that matches low-level vision. These systematic variations in face recognition across the visual field suggest that spatial properties are inherited through the visual system, causing location to influence face perception.

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Facial attractiveness mediates the effect of hijab on employability of Middle Eastern women

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The hijab is a headcover worn by Muslim women all around the world. However, this public display of religious beliefs has been shown to negatively influence personal attributes such as perceived attractiveness and intelligence. This study investigated whether women who wear the hijab are perceived to be less attractive, and less employable, and whether facial attractiveness mediated the relationship between the hijab and employability. Participants (N=131) were asked to review the CVs of 3 candidates each for a hypothetical job vacancy, rate them on facial attractiveness, and decide whether the candidates should be hired. Participants were randomly allocated to either Condition 1, where they saw 2 CVs with images of women wearing the hijab and 1 CV with an image without the hijab, or Condition 2, where 2 CVs had images without a hijab and 1 CV included the hijab. Results showed images with the hijab were rated as significantly less attractive than those without the hijab; and while the hijab did not predict employability, this relationship is mediated by facial attractiveness, whereby images of women wearing the hijab that were perceived to be less attractive were also rated lower on employability. These findings aid our understanding of the negative influence a hijab has over perception of attractiveness and shed light on the bias that could emerge in recruitment and selection processes.

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Perception of negative facial emotions and schizotypy: Prior knowledge attenuates individual sensitivity differences

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Recognition of facial emotions plays a crucial for understanding interactions and adaptive social behaviour. It is known that schizotypal traits are associated with less accurate emotion recognition. In particular, there seems to be a bias towards the perception of negative emotions. We investigated whether individual perceptual differences linked to schizotypal traits are modulated by prior knowledge. A total of 91 participants (21 males, age range 18-60 years) took part in our study which was implemented on the online platform Testable. We used 60 faces taken from the KDEF database that were presented showing either a fearful or a neutral expression. Participants had to detect the fearful faces. Performance was quantified by d' as a sensitivity index. In order to evaluate the effects of prior knowledge, we presented the faces as two-tone images. Without appropriate knowledge, these images can barely be disambiguated. Exposure to the full image information subsequently allows a coherent and robust percept. We determined discrimination performance before and after providing full image information. Schizotypal traits were measured by two established scales that focus on perceptual aberrations. We found that before exposure to full face images, schizotypal traits were linked to higher sensitivity for fearful faces. However, this link was cleared by providing prior knowledge on the emotional faces. Less pronounced schizotypal traits were associated with a more pronounced performance benefit. Our findings suggest that schizotypy in the typical population critically shapes the perception of negative emotional faces, but that disambiguation by top-down processing attenuates individual differences.

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Ensemble perception occurs for trustworthiness impressions

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Trustworthiness impressions are fundamental social judgments with far-reaching consequences in society. Most research has focused on individual facial characteristics that make a face trustworthy. However, in everyday life faces are often encountered in crowds. It has been proposed that our visual system deals with the large amount of facial information in a group by extracting summary statistics of the crowd (ensemble perception). Here, we investigated whether observers can extract an ensemble percept of trustworthiness from multiple faces. Across three studies, participants were presented with crowds of faces and were asked to report their average level of trustworthiness. In Experiment 1, participants were asked to perform an adjustment task. To rule out subsampling, we tested ensemble recognition when 1, 2, 3, 4 or 5 faces were displayed. These control set size conditions allowed us to simulate participants' estimates if they had randomly subsampled a subset of faces from the crowd. We measured participants' errors across set size conditions, and found that participants increasingly integrated trustworthiness information from our set of faces, thus ruling out subsampling. In Experiment 2, we replicated the ensemble perception result with an explicit trustworthiness judgement task. Finally, in Experiment 3, we showed that participants were able to extract an ensemble perception of trustworthiness even across different identities. Taken together, these results demonstrate that ensemble perception occurs at the level of impressions of trustworthiness. These critical social judgements do not only occur for individual faces, but are also integrated into a unique ensemble impression of crowds.

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Poster session 20. Perception & Action - II

Use of position and motion signals in saccadic and goal-directed arm movements

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Directing one's movements towards a moving target requires combining position and motion signals to predict where the target will be in the future to overcome inherent sensorimotor delays. Impairing the computation of motion information (e.g., by using isoluminant targets) results in using a delayed representation of the target for saccade planning, which causes saccades landing at positions where targets were ~100 ms before saccade initiation. Here we compare the effects of impairing target's motion information for saccades and for manual interception using a step-ramp paradigm. Targets' steps were of 14 cm upwards with respect to an initial fixation point, and horizontal ramps were of 5, 10 and 15 cm/s. In different trials, targets could be defined by first- or second-order motion. The experiment consisted of three conditions. In one condition, participants had to make a saccade towards the target and pursue it as accurately as possible with their gaze. In another condition, participants had to try to saccade at the target and intercept it by tapping on it. In a third condition participants had to try to intercept the target while keeping gaze at the initial fixation point. Second-order motion impaired motion information causing longer saccadic latencies and landing errors of ~100 ms. However, accuracy in manual interception was similar for first- and second-order motion targets. Moreover, intercepting the targets without looking at them did not seem to worsen accuracy. These results suggest differences in how position and motion signals are used to guide gaze and hand movements.

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Is there Garner Interference in Manual Estimation?

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The Perception-Action Model (PAM) assumes that visual information in the human brain is processed qualitatively differently in dorsal and ventral cortical streams. Some evidence for PAM comes from the Garner paradigm, that tests selective attention to stimulus features. It has a baseline condition, where only task-relevant stimulus variation occurs, and a filtering condition, where task-relevant and irrelevant variation occurs. Longer reaction times (RTs) in the filtering condition compared to the baseline condition indicate Garner interference. Ganel & Goodale (2003, Nature) observed Garner interference in perception and manual estimation (both arguably ventrally processed), but not in a visuo-motor grasping task (arguably dorsally processed). We replicated this experiment (N=24) and confirmed previous findings in perception and grasping, but found no Garner Interference in manual estimation. Hesse & Schenk (2013, Behavioural Brain Research) proposed an alternative account for Garner interference, citing methodological differences in RT profiles of the tasks. In a modified perception task, they varied how soon the participants' decision was required. They predicted and found Garner interference in the short but not long condition. We extended this to manual estimation (N=8) by manipulating the distance between the start position and the location of the manual estimate. Again, we found Garner Interference in the short, but not in the long condition, thereby corroborating the Hesse & Schenk (2013) account. Overall, Garner interference may depend on RT profiles, rather than type of processing. Consequently, claims about different processing in perception and action based on Garner interference may need to be reassessed.

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Freedom of movement alters size perception.

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In our daily lives, we generally see an object and judge the size of it while moving. A great number of studies showed the relationship between our movement and size perception in the visual system. However, it is still unclear how the degree of movement freedom correlates size perception. With a head-mounted display (HMD) that allows us to visually manipulate the degree of movement freedom, here we examined how the degree of movement freedom change visual size perception. In the experiment, one of five different size of a fish was randomly chosen and presented in the left or right side of a participant in one trial. Participants took a look at a fish for six seconds and reported the size of it, big or small. They performed the task under the different degree of movement freedom conditions, 1/4, 1/2, 1 (normal), 2, and 4 times as movement in the real world. The results showed that JND (just noticeable difference) was changed with the degree of movement freedom: Higher freedom of movement increased the value of JND.

This indicates a kind of trade-off relationship between freedom of movement and precision of visual size perception. Moreover, difference of movement freedom might lead to disagreement of size perception among people. This finding provides us with a clue to understanding a great deal of controversy of size of a fish that got away.

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A new perspective on the Weber's law in action

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Weber's law, the psychophysical principle that precision decreases with stimulus magnitude, extends across all domains of human perception, with the exception of visually guided grasping actions. Converging evidence shows that the variability of the maximum grip aperture is unaffected by variations in object size, in striking contrast with the variability of perceptual estimates, which instead increases with object size. However, the violation of the Weber's law has been observed almost exclusively in grasping actions. It is thus unclear if this violation depends on the specific characteristics of grasping behavior or if it is an attribute characterizing visuomotor actions in general. To contrast these two views, we examined the Weber's law in a new action task, the two-finger pointing task. Participants reached for and simultaneously touched, with the thumb and index fingers, two targets placed at different distances from each other (similar to hitting a two-note chord on a piano). In line with the grasping literature, we observed that the variability of the maximum inter-finger separation was unaffected by the distances between targets, a clear violation of Weber's law. Conversely, in adherence with the Weber's law, the variability of the inter-finger separation at the moment the fingers touched the targets increased with larger between-target distances. These results suggest that the Weber's law might be regularly at play, but can be captured only when the measures are closely related to the actual goal of visuomotor actions.

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(Im)Precision grip: No scaling to object height when grasping very thin objects

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In grasping studies, maximum grip aperture (MGA) is commonly used as an indicator of the object size representation within the visuomotor system. However, it has been argued that a number of additional factors such as movement safety, comfort, and efficiency affect the scaling of MGA to object size - thereby potentially masking perceptual effects on actions. The modulating effects of biomechanical constraints on grip aperture have been shown for object sizes that approach the biomechanical limits of the hand. Similar effects may also exist when grasping very tiny objects, but to our knowledge, never have been explored before. Here, we asked participants (N=26) to either grasp (action task) or manually estimate (perception task) very thin objects of varying height (0.5, 1, 1.5, 2, 2.5, 3, 4, and 5 mm) using their index finger and thumb. Both tasks were performed visually open-loop and participants' hand movements were measured using an electromagnetic tracking system. We found that for manual estimation, perceptual estimates linearly increased with object height (slope of 1) and also adhered to Weber's Law (i.e., variability increased with object height). For grasping, however, MGAs did not scale with object height but remained approximately constant. We speculate that in tasks where the natural relaxed hand opening exceeds the MGA that would be used to grasp an object safely, the motor system forgoes scaling thereby decreasing effort and ensuring comfort of the movement. The findings highlight again that the reliability of MGA as an indicator of object size is strongly task-dependent.

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Stumbling affords remembrance: Perceptual and behavioral engagement with a Holocaust memorial

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The Umwelt is full of affordances normatively embedded in the socio-cultural context. The Stolpersteine (Stumbling Stones) project is the worlds' largest decentralized project of commemoration, specifically to bring victims of the Nazi regime to mind. The standardized "stone" is a squared inscribed brass plaque (96 mm x 96 mm) inserted into the sidewalk, creating high salience due to distinctive texture and material. The memorial plaques deliberately disrupt any pedestrian's efficient walking effort—people literally stumble upon history and engage with the victims. We observed the engagement of ~700 pedestrians with Stolpersteine across three different locations in Bamberg (Germany). We manipulated salience by placing grave candles beside the stones. The majority of N = 355 spotted people who showed trajectories directly crossing the

Stolpersteine did not tread on the stones (~94%) and showed little observable remembrance behavior (28% inspected the plaque visually while walking by; 6% stopped due to the plaque). Presence of a grave candle (intermittently put aside, n = 194 pedestrians) increased the occurrence of visual inspection (46% vs. 6%), dodging movements (12% vs. 2%), and stopping and reading of inscriptions (9% vs. 2%). At the same time, people trod less on the stones (2% vs. 11%). Visual perception of the stones from afar seems to alter the affordance of pedestrians normatively. The candle clearly emphasized the affordance to commemorate. Stumbling – regardless if literally or only visually - even if rare, affords retraction from automatic action and opens the opportunity to reflect and elaborate.

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Sense of agency over appearance and movement of an object

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When an action causes a sensory outcome, one feels a sense of agency, a feeling that "I caused the outcome." Sense of agency can emerge when an action makes an object appear or moves it. The present study examined the difference in the sense of agency between appearance and movement of an object by employing an implicit measure of sense of agency, the intentional binding (i.e., subjective temporal interval compression between action and outcome), and explicit rating of sense of agency. In the appearance condition, participants pressed a space key and observed a circle presented on the right or left on the monitor. In the movement condition, participants observed the circle with a right- or leftward apparent motion. Participants estimated the temporal interval between the keypress and outcome per trial and rated their sense of agency over the outcome per block. The implicit measure results suggest that a sense of agency emerged in the appearance but not in the movement condition. However, the agency rating showed no difference between conditions, suggesting a dissociation between implicit and explicit processes of the sense of agency. In the next experiment, participants pressed the right or left key, which caused the circle's right- or leftward appearance or movement. In contrast to the previous experiment, the sense of agency emerged even in the movement condition. These results suggest that a sense of agency over a moving object requires an action that has spatial representation corresponding to the object's direction or destination.

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Computer cursor appearance in pointing tasks: the effect of cursor size

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The sense of agency is the feeling of authorship over our own actions. This can extend to tool use, including the feeling that we are in control of a virtual tool, such as a computer mouse cursor. In a previous study we found that the shape and orientation of the cursor affected perceived naturalness/agency of using the cursor as well as the movement paths in a target pointing task. This study builds on those findings by looking at the effect of cursor size. Participants performed a target-pointing task, whereby they clicked on targets at 8 different locations as quickly and accurately as possible. The cursor was represented as an arrow, similar to a regular computer cursor, either small (close to normal size) or large (increased by 500%), and was presented in varying orientations (45°, 135°, 225°, and 315°). Per set of 8 trials, blocked for cursor size and orientation, participants answered questions on the level of agency felt and the perceived naturalness of the cursor. The feelings of agency and naturalness were higher overall for the small cursor and was strongest for the small cursor in the most familiar orientation (cursor pointing top-left for righthanders). Completion times were also significantly faster with the cursor pointing top-left. Movement paths were curved in cases where the pointing direction was orthogonal to the cursor orientation. These curvatures were more pronounced for large cursors. These results support our previous findings and show that cursor size affects both pointing behaviour and the feeling of agency.

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Poster session 21. Adaptation & Aftereffects

Effects of the Number and Motion type of Gabor Patches Inducing Illusory Global Rotation on Motion Aftereffect

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After viewing a moving stimulus in one direction (adaptation stimulus), an observer perceives a stationary stimulus (test stimulus) as moving in the opposite direction (motion aftereffect [MAE]). We previously reported rotational MAE after observing vertically or horizontally drifting Gabor patch array arranged to form a square and perceived as rotating. This study aimed to fortify the previous findings by manipulating the number and motion type of Gabor patches. In the two experiments, participants were presented with horizontally or vertically drifting Gabor patches arranged to form a square except for the vertices (i.e., adaptation stimulus) for 30 seconds, followed by a solid black square (i.e., test stimulus). In Experiment 1, Gabor patches drifting vertically or horizontally were presented in the adaptation stimulus, while those drifting either inward or outward were presented in Experiment 2. The participants were asked to press and hold a key corresponding to the rotational direction (clockwise or counterclockwise) whenever they felt rotational MAE to the test stimulus. The results showed that rotational MAE occurred irrespective of the number and motion type of Gabor patches, and the duration did not differ. We will discuss these findings regarding the neural mechanisms of motion processing.

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Motion adaptation improves acuity (but size doesn't matter)

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Introduction: Acuity – the size of the smallest object/letter that can be reliably recognised- is the gold standard clinical measure of visual function. Acuity is limited by eye and by brain. However, the perceived size of an object can be changed by motion-adaptation. Viewing inward or outward motion makes subsequently viewed stimuli appear to grow or shrink respectively. Previous reports suggest that these changes in perceptual size impact recognition acuity thresholds. We set out to determine if such acuity changes are reliable, and what might be driving this phenomenon.

Materials/methods: We measured the effect of motion-adaptation to inward and outward motion on recognition acuity for crowded tumbling-T stimuli ( ). We quantified the role of crowding, individuals' susceptibility to adaptation and the potentially confounding factors of pupil size and eye movements.

Results: Adaptation to both inward and outward motion induced small, but reliable improvements in acuity (-0.037 and -0.018 LogMAR respectively) although only the former induces the target to appear larger. The magnitude of acuity-change was not correlated with participants' perceived size change to inward and outward motion-adaptation. We found no evidence that crowding, fixation stability or pupil size were associated with adaptation-induced acuity gains.

Conclusions: Adaptation to motion modestly enhances visual acuity but, unintuitively, this appears dissociated from perceived size. Ruling out fixation and pupillary behaviour, we suggest that motion adaptation may have motion direction independent incidental effects on sensitivity - akin to those arising from blur adaptation - shifting sensitivity to higher spatial frequency tuned channels, improving acuity.

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Face adaptation effects on non-configural face information

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When identifying faces, the incoming face information is matched against mental face

representations stored in memory. Previous studies showed, that these representations are highly flexible and subject to immediate adaptation following exposure to new visual information. These face adaptation effects seem to be very reliable and robust over long periods of time, suggesting a high-level processing and long-term changes in face memory. Although research on face adaptation effects seems to be well-advanced, it still lacks a systematic analysis of its generalizability to different types of face information since most research indeed focused on configural information (i.e., mostly 2nd-order relations). However, studies of our lab provide clear evidence that also non-configural face information play a significant role in the processing and storage of faces. Moreover, by applying different non-configural color alterations, we found variations in the adaptation effects, indicating a representation of face information according to different valences. The valence of face information is probably related to the relevance the information has for face recognition. The experiments presented here, are part of this study series.

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Gaze displacement thresholds for image recovery after Troxler's fading

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The phenomenon of Troxler fading has become the subject of intensive research since the beginning of the 19th century. After prolonged gaze fixation on one spot subject may experience complete image disappearance. But after eye movement or blink image may be completely restored. In this research, we have investigated how much eyes need to be moved for partial or complete image restoration.

The stimulus – blurred ring extending 14° of the visual field was displayed on a monitor screen. The subjects were instructed to look at the fixation spot in the middle of the ring and continuously report whether a stimulus was fading versus recovering during a classical Troxler's fading task. When the subject reported complete fading of the stimulus, the position of the fixation spot was moved horizontally or vertically to a new position, and the subjects were required to shift their gaze to a new fixation spot and again report the fading or recovery of the stimulus.

We found that a certain threshold of gaze displacement should be reached in order to facilitate an image recovery after Troxler fading. Partial recovery of the stimulus was observed after the gaze was moved by 7' and the full recovery was observed after 18'. Similar thresholds for stimulus recovery were observed for vertical and horizontal gaze displacement.

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Passive visual stimulation induces fatigue or improvement depending on cognitive load

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Theories of mental fatigue disagree on whether performance decrement is caused by motivational or functional alterations. We tested the assumption that keeping neural networks active for an extensive period of time entrains consequences at the subjective and objective level – the defining characteristics of fatigue – when confounds such as motivation, boredom and level of skill are controlled. We reveal that passive visual stimulation affects the performance of a subsequent task that is carried out in the same portion of visual space. This outcome, consisting either in an enhancement or deterioration of performance, was determined by the participants' level of cognitive load and arousal, which were manipulated through variations in the difficulty of concurrent auditory tasks. Thus, repeated stimulation of neural networks leads to their altered functional performance, a mechanism which may play a role in the development of global mental fatigue.

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Poster session 22. Art & Aesthetics

What makes an environment restorative? New insights from multi-arrangement and representational similarity methods.

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Nature environments are generally thought to be psychologically and physiologically more restorative than urban environments, with most literature arguing that nature possesses fundamentally different qualities to other environmental categories. However, little is known about what these qualities might be, as experiments are biased in stimulus selection and suffer from design flaws that limit the number of comparisons that can be sensibly made between different environments. Here, we implemented spatial multi-arrangement methodology to obtain comparisons between 92 images containing a wide range of nature and urban scenes from across the world (46 nature, 46 urban). Across three counterbalanced sessions, all participants (N=18) compared the 92 images for visual discomfort, liking and fascination as these are qualities suggested in the literature to be linked to restoration. Data (N=54 across all three criteria) are presented in the form of dissimilarity matrices and were analysed using multi-dimensional scaling and representational similarity analysis. Dissimilarity matrices exhibit a nature and urban similarity distinction for all three criteria, with analyses revealing that all criteria are related. Furthermore, multi-dimensional scaling confirmed that liking and visual discomfort are the most tightly linked, while fascination diverges. Implications for the use of multi-arrangement methodology in aesthetics and vision research are discussed, as well as the significance of these findings to existing theories and experimental results in the field.

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A neural network in lockdown loses its ability to appreciate nature

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Exposure to nature results in positive benefits to cognition, affect, and well-being. However, rapid urbanization has led to a decrease in opportunities for people to interact with nature, which has been exacerbated by the indoor lockdowns due to the pandemic. The danger is that a lack of nature exposure may lead to an indifference towards nature, potentially causing the beneficial effects of nature to be lost. However, it is unclear how longterm isolation would affect people's appreciation for nature. Thus, we began to examine these effects using deep learning. We trained the Neural Image Assessment convolutional neural network with images from the Aesthetic Visual Analysis (AVA) dataset, using the "landscape", "urban", and "indoor" labels to train models exposed to either nature, urban, or indoor images only, or a combination of the three (baseline). We then tested each model on a separate test image set containing images from all three categories. A regression analysis revealed an interaction between the trained model and the test image type ($F(6,3108) = 14.25$, $p < 0.001$), such that the lockdown and urban models resulted in lower aesthetic scores for nature images compared to baseline. Conversely, the nature model resulted in higher aesthetic scores for urban and indoor images compared to baseline. Our findings suggest that human-nature interactions may elicit a more positive appreciation of aesthetic beauty, while lockdowns and urbanization decrease appreciation of nature. These models provide initial evidence of the potential long-term negative impact of self-isolation and urbanization on the capacity to appreciate nature.

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Understanding the Aesthetic Experience: The Relationship Between Aesthetic Attributes and Emotional Competence.

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Whilst there is research supporting the relevance of complexity, regularity and symmetry in aesthetic appreciation, very little is known about the interplay between such attributes and the underlying emotional processes. The current study aims to investigate the association between attributes of perceived beauty, and emotion – measured on the intrapersonal scales of the Profile of Emotional Competence, PEC. Most notably, this was done in an online platform (Qualtrics) recruiting participants through Prolific. Synthetically generated 'moss patterns' with 7 well-defined levels of complexity, regularity and symmetry were presented in an online survey and rated by participants on a scale of aesthetic preference in terms of liking', followed by a 25-item questionnaire measuring participants' intrapersonal emotional competence on a 5-point scale.

Our initial analysis shows clear profiles for aesthetic attributes and significant differences between the peaks of distribution. The emotional competence scores spread widely across the range of the scale, with a peak in the mid-high range. Through our preliminary analysis, we could not establish a strong association between any of the aesthetic attribute scores and the emotion scores. However, an association should be revealed with a more in-depth analysis. In this context, it will be discussed whether fine discrimination may be difficult to pick up within online experiments.

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Looking for balance: The sampling of visual information when judging the composition of abstract art

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In our preceding interactive study we have found consistent responses when participants were asked to indicate spatial balance points in abstract paintings. Here we decided to measure in 30 'art-naïve' students where they look while doing the task with same works of art. While their eye movements were recorded, participants were asked to search for the "balance point" or the "main center" of each artwork presented separately on the monitor. By pressing 'space' the painting disappeared, recording was stopped and a gray rectangle with the dimensions of the seen artwork appeared. Participants indicated the location of the perceived balance point of the painting by moving a gray disk with the mouse.

We found that participants' scanpaths appeared to reflect the general composition of the different paintings, i.e. size and distribution of shapes, contours and lines and their overall orientations. Moreover, participants' fixations also included the locations of the later indicated balance points. When we tried to match the fixation areas and scanpath patterns with different models used for visual saliency and scanpath analysis, we found that on average bottom-up saliency models outperformed object based ones, and that performance improved when the central

bias was included. However, low-level models could not fully account for the scanpath patterns since we also found marked individual differences in terms of overall dwelling times and amount and range of saccades and marked differences with respect to the performance varied across paintings.

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The outside, the inside, and the in-between: what can Virtual Reality do for the Arts and Sciences?

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Conversations between artists, psychologists and neuroscientists trigger a plethora of diverse, difficult, and exciting questions such as the function of human aesthetic experience and the mechanisms underlying judgements of beauty. Here we ask how frames function in arts and perception, particularly in relation to how they clarify 'ownership' of space in 2 and 3 dimensions. We start with a comparison of framing used in paintings, object design, and architecture, and highlight the skilful and precisely controlled interaction in three-dimensional space.

Cross-over between real and illusory precepts in a confined space is exemplified in the, Santa Maria sopra Minerva, Rome (Filippino Lippi, 1493), which presents an intriguing Carafa Chapel interaction between physical and painted structures, real and illusory depth, and different layers of narrative. In our contributions we will present (a) recordings from participants wearing mobile eye trackers whilst moving freely through the chapel and exploring areas of the sculptures, frescoes, frames, and paintings that they find attractive, intriguing, or puzzling; and (b) the first steps of a complete three-dimensional reconstruction of the Carafa Chapel based on a 3D-laser-scanning of this environment, combined with photogrammetry, that will provide a VR model to be used for more comprehensive studies of observer experience in this environment.

Acknowledgement: the 3D scanning of the Carafa Chapel was made possible by comprehensive support from the British School at Rome.

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Using Hidden Markov Models for analysing mobile eye-tracking data from visitors of an art exhibition

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In most scene viewing lab experiments, a priori determined areas of interest (AOIs) usually drive the allocation of gaze at relevant locations. In other settings, it can be too reductive or impossible to determine such AOIs. This is the case when analysing eye movements of art exhibition visitors viewing abstract artworks (e.g., walls with painted colour gradients) with mobile eye-trackers. In such cases, comparing gaze distributions (heatmaps) is possible but it disregards that oculomotor behaviour is sequential. Alternatively, scanpath comparison methods reduce the scanpath differences to single distance metrics or a few summary statistics, complicating their interpretability and making them unsuitable for exploratory analyses.

Instead, Hidden Markov Models (HMMs) can represent visual exploration more meaningfully, while incorporating a dynamic aspect. We recorded the eye movements of 74 visitors of an exhibition while they observed 16 artworks by Pieter Vermeersch. We modelled each scanpath using a data-driven variational approach (implemented in EMHMM Matlab toolbox) where the HMM's states represent the AOIs and the transition matrix represents movements between AOIs. Using variational hierarchical expectation-maximization, we summarize the viewing strategies adopted by clusters of participants. To evaluate their consistency across parameter settings, we compare HMMs fitted with different numbers of AOIs. Finally, we evaluate the impact of Markov models' memory-less nature by comparing them with geometric methods for scanpath comparison that are insensitive vs. sensitive to sequential information (Eyenalysis, dynamic time warping). Overall, we comprehensively describe HMM modelling of eye movements, highlighting their strengths and limitations for analysing mobile eye-tracking in ecological contexts.

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Isolating Systematic Patterns in Museum Navigation Behaviours via Cross-Recurrence Quantification Analysis

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We examined the behavioural patterns of 109 free-exploring museum visitors using mobile eye-tracking at the Pieter Vermeersch exhibition at M Museum in Leuven, Belgium.

The exhibition spanned across four rooms and featured contemporary artworks, consisting of large gradient paintings on either marble slabs with sections of the marble exposed or canvas, and architectural installations, consisting of brick and cinderblock walls separating the rooms and entire gallery walls painted with a gradient. Participants' behaviours within the museum were coded according to our recently developed taxonomy of museum navigation behaviours (TaMuNaBe; Linden & Wagemans, 2021). Each participant's behavioural stream was quantified using both recurrence quantification analysis (RQA), which provides measures of the systematically repeating sequences present within an individual participant's navigational series, and cross-recurrence quantification analysis (CRQA), which provides measures of the systematically repeating sequences between participants' navigational series. Using RQA, we isolated the repeating behavioural sequences to determine if participants displayed specific navigational styles. Individual participants might display a consistent local-global viewing pattern by, for example, zooming in and out while viewing many artworks. Using CRQA, we isolated the behavioural sequences that repeated across participants, to examine whether specific artworks or art installation features elicited specific behavioural responses from a wide range of participants. The marble slabs, for example, regularly had people zoom in to view finer details of the stone, and shift to view the artworks on a sharp angle to see the texture and depth along the edges of the artwork.

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Congruency effects in crossmodal art perception: differential cortical activations

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Many aesthetics studies investigate the perception and emotional evaluation of art unimodally. In this study, we aimed to investigate how art perception is affected by emotional congruency/incongruency of crossmodal (auditory and visual) information by using fMRI. Paintings and music excerpts were first piloted and rated as happy or sad, both in original format and in their Fourier scrambled counterparts (as to rule out the effect of semantic content in a control condition). Stimuli were chosen such that the original stimuli had large or small emotional rating differences with the Fourier scrambled images. The experimental design included unimodal presentations of the paintings and crossmodal presentations in which music excerpts were played during the presentation of the paintings. In these conditions, the played music was either emotionally congruent or incongruent with the painting. We tested 20 participants with fMRI, and we found that, as expected, the crossmodal-unimodal contrast showed a significant increase in activation for auditory and multimodal areas (Heschl's gyrus, parietal regions), and that the activation for unimodal-crossmodal contrast was stronger in vision related areas (lateral occipital cortex, inferior temporal gyrus). Interestingly, the congruent-incongruent contrast revealed activations in the higher visual cortex (lingual gyrus, inferior temporal gyrus) and emotion related areas (insular cortex, putamen). The contrast of original versus Fourier scrambled paintings revealed widespread activation in areas related to memory and complex visual processing (hippocampus, lingual gyrus, LOC and fusiform gyrus). We will discuss how these results relate to the experienced impact of adding music to a painting.

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Experimental aesthetics without semantics

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Observers can easily assess how beautiful/ugly they consider an image to be. However, this aesthetics decision is influenced by both perceptual factors (which determine bottom-up neural processing) and cognitive factors such as contextual variables (which determine personal aesthetic preferences). This dualism makes the problem of predicting aesthetic responses particularly difficult from a computational point of view. In this work we simplify the problem by creating a database of images devoid of contextual information (i.e. "semantics") which contains only images of natural objects. To address the strong bias of such databases towards highly valued (beautiful) scenes, we incorporate images that were intentionally modified to make them "uglier". We then ask observers to evaluate the aesthetic value of every image using a crowdsourcing paradigm (10426 images, 100 valuations each). This unbiased, low-semantics database allows us to study the low-level visual properties that are more likely to explain observers' aesthetic response. Our results show that the strongest candidate is the "spatio-chromatic fragmentation" (the spatial distribution of patches of similar chromatic properties, r=-0.51), followed by mirror symmetry (r=-0.34), depth (r=-0.18) and global contrast (r=0.22). For comparison, we run the same analysis using a more traditional aesthetics image database (AVA, CVPR2012) with inconclusive or negative results.

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Poster session 23. Lightness, brightness

EIGHT COMPUTATIONAL MODELS VS. FOUR LIGHTNESS ILLUSIONS

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In the previous study, we tested four lightness illusions with four computational models of lightness perception (ODOG, High Pass, RETINEX and Markov Illuminance and Reflectance). The results showed that these models were good for predicting simultaneous contrast types of illusions, but not for reversed contrast (such as White's or Economou's). In this study, we extended number of tested models (adding ODOG-2, L-ODOG, FL-ODOG and Dynamic Decorrelation) and introduced four new illusions, more challenging reversed contrast illusions (Wedding cake, Dungeon), and assimilation (Checkerboard and Bullseye illusion).

Four illusions, each consisting of the same three luminance levels (6, 69, 145 cd/m2), were 1) shown to 85 human participants in an online experiment and 2) tested with the mentioned eight computational models.

The participants produced typical results on these four illusions and their data were directly compared to models' predictions. None of the eight tested models was able to match absolute lightness levels obtained by humans. However, as before, some computational models were able to match the direction of the produced illusory effects. FL-ODOG and Dynamic Decorrelation models were able to predict obtained illusion directions for all illusions. RETINEX model was able to match the effect for Dungeon illusion, while other five models predicted effects that are contrary to obtained human lightness matches. The current models do not seem to accommodate complementary visual processes (contrast vs reverse contrast, and contract vs. assimilation) in the same manner as visual system. The only exception is FL-ODOG that applies orientation and spatial frequency specific normalization.

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Contextual modulation in contrast perception: the role of flankers contrast

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Contrast perception, the ability to distinguish differences in luminance between two surfaces, represents one of the earliest processes that V1 carries out. Such deceivingly simple task is affected by contextual modulation of contrast in space and time. Concerning the former, two well-known phenomena in vision sciences are contrast computation and collinear modulation, in which the presence of collinear flankers increases (inhibition) and decreases (facilitation) contrast sensitivity for a central gabor patch. Concerning the latter, contrast adaptation, i.e. a decrease in neural response after a long exposure of a contrast stimulus, represent perhaps the most famous contrast modulation effect to date. All these effects seem to have their neural substrates in the early visual cortex. Here, in a series of psychophysical experiments, we studied the effect of low flankers contrast and the effect of flankers contrast adaptation on the magnitude of collinear modulation by testing whether these factors can reduce or increase collinear inhibition and facilitation. Results showed that inhibition turns into facilitation with low contrast flankers. Moreover, we found dissociation in the effect of collinear flanker adaptation, which reduced contrast thresholds in the inhibitory configuration and increased them in the facilitatory configuration. Therefore, contrast sensitivity can be affected by changing the contrast of or by adapting portions of visual field outside the receptive field of the units processing the contrast of the target (i.e., the flankers). These results further reinforce the idea that collinear modulation, contrast perception and contrast adaptation share common neural substrates, likely located in early visual cortex.

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Perceptual scaling constrains the shape of brightness transfer functions in humans and models

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The common standard to measure (apparent) brightness is (asymmetric) matching. The observer adjusts the physical luminance of a test patch so that it matches the brightness

of a reference patch. The task rests on the assumption that there are characteristic functions that link luminance to brightness for test and reference, the so-called transfer functions. Test and reference appear identical for identical brightness values. The corresponding luminances are the measured matches. Using simulation we illustrate that matching cannot reveal the shape of the transfer functions whereas scaling methods can. We further show that empirically derived brightness scales predict perceptual matches.

Specifically we used Maximum-Likelihood Conjoint Measurement (MLCM), to measure perceptual scales in White's effect. We measured separate scales for each patch in White's effect. The scales were non-linear, and so was the difference between them. We also collected brightness matches for both test patches and found that matches predicted from the scales corresponded to the empirical matches.

We then compared the scales to model output from the ODOG family of brightness models. In contrast, their transfer functions are best characterized as linear with a fixed offset. Thus, the present scaling data provide a new way to further constrain image-computable models of brightness perception.

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EEG Correlates of Inhibitory Processes Involved in Paracontrast Masking

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Forward masking has been frequently used to investigate the temporal dynamics of visual processing. The neural correlates of this paradigm, however, are not fully understood. In the current study, we examined paracontrast masking (a type of forward masking) under different onset timing between mask and target (SOAs) and mask-to-target contrast ratio (M/T ratio) conditions. We recorded neural activity (Electroencephalography: EEG) while observers performed a contour discrimination task on the target. As the M/T contrast ratio increased, the decrease in behavioral accuracy due to paracontrast became larger at short SOAs. Together with previous research, these significant modulations suggested that M/T ratio alters brief inhibition, mainly operating at short SOAs. Our EEG analysis revealed non-linear interactions between target and mask stimulations in the early and late neural activities (i.e., components). While the early component was located over occipital/parieto-occipital electrode sites, the later was mainly over parietal regions. More importantly, the M/T contrast ratio altered the amplitude of these interactions similar to the behavioral results. Overall, these EEG findings revealed early, and late neural correlates of inhibitory processes involved in paracontrast masking. [This work was supported by the Scientific and Technological Research Council of Turkey (TUBITAK Grant 119K368).]

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The usability of an ultrabright off-the-shelf monitor for vision testing

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Testing the visual system under extreme conditions might be a sensitive diagnostic approach. Instead of using cumbersome custom devices, this study evaluated the usability of an ultrabright off-the-shelf monitor (DynaScan DS472LT6) in assessing contrast sensitivity (CS) and visual acuity (VA) under extremely high and low luminance levels using the Freiburg Acuity and Contrast Test. After power-on, the monitor required around 30 minutes to reach final luminance. Following a luminance change, the monitor required at least three minutes to stabilise. Log CS and logMAR VA were measured three times at six luminance levels (0.6–5500 cd/m2) in 16 healthy participants with refractive error with and without correction. The coefficient of variation (CoV) and the influence of refractive state and luminance on VA and CS were assessed. The average CoV was 0.10. VA and CS significantly improved with increasing luminance for both refractive states ($p<0.001$). The ICC was 0.90 ($p<0.001$). Although the general difference in CS or VA between corrected and uncorrected refractive states was approximately proportional to the refractive error, the gain in CS with increasing luminance was significantly lower for corrected than for uncorrected refraction ($p=0.017$); this was not significant for VA ($p=0.45$). Conclusion: The DynaScan DS472LT6 monitor can be used successfully to access VA and CS at extremely high luminance. Changes in VA and CS with luminance differ on their dependence on refractive error.

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Brightness contrast alters perceived object distance in virtual environments

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Brightness contrast between figure and ground serves as a cue to distance perception. Objects with a marked

brightness contrast relative to the background appear closer than objects with a brightness similar to the background, largely independently of the polarity of the contrast.

Previous studies have mainly focused on the perception of small objects under artificial viewing conditions. To investigate whether this finding can be transferred to more ecological scenarios, we conducted two experiments using different virtual environments. In Experiment 1, subjects estimated their egocentric distance to an object placed in an open field. We varied the average luminance of the environment (4.96, 49.35 cd/m^2) and the luminance (3.95 to 62.39 cd/m^2), size (0.25 m^2 to 16 m^2), and distance (4 to 12 m) of the object. In Experiment 2, subjects viewed an interior space and estimated their distance to the opposite wall or to an object placed in front of it. We varied the luminance of the wall (9.11, 73.69 cd/m^2) and of the object (7.26 to 91.73 cd/m^2), as well as the distance of the wall from the observer (5.8 to 10.3 m).

Our results show that the effect of brightness contrast can be transferred to more ecological scenarios and remains robust across the variations of object and background. In addition, in the interior space, we found that brightness contrast affected the perceived distance of the object but not that of the wall. Thus, brightness cues are processed differently in the distance perception of surfaces versus objects.

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Examining the Effects of Contrast Ratio on Metacontrast Masking with Electroencephalography

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Visual masking is a powerful illusion to investigate the dynamics of sensory and perceptual processing. Since masking paradigms can lead to aware and unaware states, it has also found increasing applications in visual awareness and consciousness studies. The suppression of target visibility by a following and spatially adjacent mask is called metacontrast masking. Yet, the cortical processes underlying this common masking type are still subject to debate. In the present study, we investigated the effects of mask-to-target (M/T) contrast ratio on metacontrast masking using electroencephalography (EEG). We manipulated M/T contrast ratio across various onset timing between target and mask (SOA) and employed a contour discrimination task to assess target visibility and quantify metacontrast masking. The behavioral findings revealed typical U-shaped masking functions for both low and high contrast ratios with strong suppression of the target visibility at intermediate SOA values (around 40-80 ms). More importantly, the amount of suppression at these SOA values was also significantly modulated by the contrast ratio. To understand the EEG correlates of these alterations, we analyzed both event-related potentials (ERP) and low-frequency oscillations located over occipital and parieto-occipital scalp sites. ERP results showed a significant SOA dependency on visual awareness negativity (VAN, after 140 ms) component range. Evoked oscillatory activities also revealed a U-shaped SOA dependency in the theta-band response (4-8 Hz). Overall, these findings emphasize robust modulations of metacontrast masking at intermediate SOA values due to the contrast ratio. [This work was supported by The Scientific and Technological Research Council of Turkey (Grant: 119K368).]

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Poster session 24. Clinical Aspects & Clinical Populations

The perception of Illusory Line Motion in Parkinson's Disease

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Illusionary line movement (ILM) is an illusion where a flash of light at one end of a bar preceding the immediate presentation of bar results in the perception of motion receding away from the flash. One prominent explanation for the occurrence of ILM asserts that the brief flash commands the individual's visual attention, creating an attentional gradient where the flash is the centre with a gradient decay away from this point. Subsequently, the parts of the bar nearer the flash are detected earlier than more distant parts. Thereby giving rise to the perception of motion. In Parkinson's disease (PD), the degeneration of dopaminergic neurons results in profound motor and non-motor deficits. One of the non-motor deficits is enhanced distractibility. Specifically, individuals with PD show reduced ability to inhibit reflexive responses in both eye tracking and behavioural tasks. This enhanced distractibility/impairment in inhibiting reflexive responses suggests that individuals with PD display enhanced exogenous attentional control mechanisms, and so would display enhanced susceptibility to ILM. This study investigated the influence of PD, on the susceptibility to ILM. Sixty participants with mild-to-moderate idiopathic PD and forty healthy older

adults provided estimates of the direction of motion of stationary blocks. Both healthy older adult controls and individuals with PD showed the presence of ILM. Our findings reveal that there was no evidence that individuals with PD experienced ILM more or less strongly than healthy controls. Alterations in exogenous attentional control in mild-to-moderate PD does not influence individuals with mild-to-moderate PD's perception of ILM.

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Visual orienting responses in children with cerebral visual impairment (CVI) due to different aetiologies

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Purpose: Visual orienting responses (VOR) measured with an eye-tracker give valuable information for diagnosing CVI, as they provide objective and quantitative measures of the timing and accuracy of stimulus-driven eye movements. Currently, it is unknown whether there are differences in stimulus-driven eye movements between children with CVI with different aetiologies. The goal of the current study was to compare the VOR in children with CVI due to prenatal, perinatal, postnatal or genetic causes.

Methods: A total number of 59 children with diagnosed CVI aged 6 to 11 years were included in the study (prenatal group n=11, perinatal group n=19, postnatal group n=11, genetic group n=18). All children underwent visual function examination according to the Dutch CVI diagnostic guidelines. Eye movements were recorded with the Tobii T60XL, using a standardized approach presented by Kooiker et al. (2014). Outcome measures were: cartoon reaction to fixation time (RTF), cartoon gaze fixation area (GFA) and motion RTF.

Results: There were slower motion RTF times (442ms (370-592), 95% CI:[451.84-550.64]) and group differences in motion RTF in children with CVI due to genetic aetiology only ($p<0.05$). There were no group differences in median cartoon RTF and GFA (grand median respectively, 252ms (226-292) (95% CI:[251.13-286.46]) and 2.23 degree (1.91-3.00) (95% CI:[2.31-2.68]))

Conclusions: This is one of the first few studies to describe VOR in children with different aetiologies of CVI. According to the results, motion processing can be affected in children with CVI with a genetic aetiology.

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The FreiBurger: A new optotype for P300-based acuity estimation

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Objective estimation of visual acuity is important in cases of suspected malingering and misrepresentation. For this purpose, the P300 of the event-related potential has proven useful even in certain cases where other objective methods fail. In contrast to visual evoked potentials, it also allows for the use of standard optotypes, such as the Landolt C. However, patients with large visual field defects have difficulties finding the gap in the C quickly enough to be reflected by the P300. We assessed a new optotype that is loosely based on the Landolt C, but with the critical detail (= stimulus component to be identified) always in the center of the optotype, abolishing the need to search for it. We performed three experiments comparing the new optotype to a standard Landolt C under conditions of strongly reduced acuity (requiring very large optotypes), addressing the following questions. (1) Is the acuity outcome comparable in the absence of visual field defects? (2) Does the new optotype perform better in psychophysical testing with simulated visual field defects? A concentric loss of visual field was approximated by placing an occluder with a small central orifice anteriorly of the observer's eye. (3) Does it also make P300 recordings more reliable? We found very similar acuity values with both optotypes. With simulated visual field loss, psychophysical response times were shorter and P300-based measures more reliable with the new optotype. We thus expect the new optotype to increase reliability of P300-based objective acuity estimates in patients with visual field loss.

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Altered high-level chromatic perception in Parkinson's disease

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Parkinson's Disease is a neurodegenerative disease caused by a loss of nerve cells within the brain resulting in depleted

dopamine. The disease is characterised by symptoms including slowness of movement and tremors. Additionally, measurable changes in visual performance have been reported in Parkinson's patients. Chromatic sensitivity has been assessed with low-level stimuli (e.g., a Landolt ring or 100-Hue test), with studies tending to indicate a sensitivity loss. In the current study we employed a high-level stimulus - images of natural scenes - with manipulated chromatic saturation as the dependant variable. Participants made judgments on each trial as to whether the chromatic content was over- or under-saturated. Results indicate that the Parkinson's group required increased saturation in-order to judge the colour content of the scenes as 'correct', compared to unaltered images that were judged as under-saturated. Age, young and depression matched control groups judged the unaltered scenes as containing the correct saturation level. Additionally, a significant negative correlation existed between the time since diagnosis and the psychometric function slopes indicating an increase in response uncertainty as the disease progresses.

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Investigating Developmental Prosopagnosia across the Lifespan

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Developmental prosopagnosia (DP) is a face-selective deficit characterised by severe everyday face recognition problems despite normal vision and lack of obvious brain damage. DP is widely reported to be a heterogenous condition, in both presentation and severity. Two subtypes of DP, one affecting both face perception and memory, the other affecting only face memory, have been proposed in adults but it is not currently known whether these sub-types are also observed in children and adolescents.

We report results of a large-scale systematic investigation of the nature and patterns of the underlying face processing deficits in DP across lifespan. Participants were 23 individuals aged 8 -71 years who reported difficulties recognising familiar faces (DPs) and 119 age-matched controls. Participants completed tests of low-level vision and a battery of 11 neuropsychological tests tapping the multiple stages of face processing from face detection and categorising of age and gender, through face matching to recognition and identification. Results were analysed at group and individual case level. We present main findings and compare patterns of results across four age groups 6-13, 14-35, 36-59 and 60-74 years. A key conclusion is that the current gold standard tests for DP, whilst useful, may lack sensitivity and specificity and that using converging evidence from wider range of tests can be helpful to classify DP. Preliminary results indicate that impairment mostly occurred at later stages of face processing, however five participants were impaired at a very early perceptual stage of face processing on a simple gender categorisation task.

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Improving vision in patients with pre-chiasmatic disorders: three case studies of transorbital alternating current stimulation in association with perceptual learning

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A pre-chiasmatic lesion results in a reduction of the visual field that seriously affects patient's quality of life. This condition was considered irreversible, however, in the last decade, non-invasive transorbital alternating current stimulation (tACS) was applied to these patients with the goal of activating their residual vision with positive outcomes. Moreover, it has been suggested that also perceptual learning (PL) might improve visual perception in patients with pre-chiasmatic disorders. Here, we report three case studies on patients with optic nerve damage combining tACS with a non-invasive computerized contrast detection training (Neural Restoration Training, NRT) that aimed at boosting the stimulated neurons. The new protocol was based on a 10-day treatment course including the tACS paired with NRT before and after every stimulation session. Transfer of the treatment to untrained visual functions was assessed testing the patients before and after the 10-day treatment. Results showed that tACS coupled with NRT improved, with noticeable individual differences, visual acuity, contrast sensitivity in an orientation discrimination of a range of spatial frequencies and increased the amplitude of preserved visual field. Moreover, two out of three patients reported a subjective improvement of vision in everyday life activities. Taken together, these results suggest that this innovative treatment could be effective to partially restore pre-chiasmatic vision, probably improving preserved neuronal response.

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Multivariate EEG decoding unveiled dysfunctional neural dynamics during attentional zooming in autism

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Autism spectrum disorder (ASD) is associated with hyper-focused spatial attention and with deficits in zooming-out that potentially impact global perception, but the neurocognitive underpinnings of these anomalies remain poorly understood. Here, we used electroencephalography (EEG) in children with typical development (TD; N=20) and with ASD (N=19) during a visual attentional task where a large (zoom-out) or small (zoom-in) circular cues preceded the appearance of targets at different eccentricities. To investigate the time course of attentional zooming in ASD, we used both univariate statistics and multivariate pattern analysis (MVPA), both in the cue- and target- locked time windows. Univariate cue-locked results revealed that the TD, but not the ASD, group showed greater amplitude in the posterior electrodes during zoom-in (vs. zoom-out) trials. Univariate target-locked analysis revealed a greater parieto-temporal amplitude for the target at central vs. peripheral eccentricities in both groups, but this differentiation was delayed in the ASD group during zoom-out. Cue-locked MVPA revealed that in both groups different cues elicit different neural patterns, although in the ASD group this differentiation was sustained even after the target onset, therefore being a potential source of interference. Target-locked MVPA revealed a delay in decoding target stimuli based on eccentricity in zoom-out trials in the ASD group. Overall, these findings revealed a different neural pattern during the modulation of attentional focus in ASD, highlighting alterations mainly in the zooming-out mechanism. They also suggest how MVPA might be a powerful method to uncover hidden neural dynamics in the study of visual attentional dysfunctions.

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Photobleaching as a Tool to Reversibly Induce Glaucoma-Like Symptoms in Healthy Subjects

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Glaucoma, a progressive and irreversible disease of the retina, is the leading cause of blindness. The impact of glaucoma on quality of life is severe. Diagnosis of disease onset is severely hampered by the fact that early glaucoma does not evoke pronounced symptoms. This issue is compounded by the fact that an accepted gold standard for screening is lacking, and the search for screening tools is ongoing. Development of new clinical tools requires thorough psychophysical testing to determine the parameter space of interest. Since this process is time intensive, it is not always possible/desirable to recruit patients to extensively test new paradigms. To circumvent this issue, our goal is to mimic the most salient symptoms of glaucoma in healthy subjects before transitioning to a patient population. This approach may 1) speed up development of new screening paradigms, and 2) improve screening quality. Here, we focus on reduced contrast sensitivity, which results in increased reaction times to visual stimuli and which can be assessed with eye-movement perimetry in glaucoma patients. We demonstrate that it is possible to reversibly and selectively increase reaction times of healthy subjects by exposing them briefly to bright, non-harmful light (photobleaching). Our protocol allows us to impose two-dimensional reaction-time patterns onto the healthy retina to mimic well-known glaucoma patterns, e.g. a superior arcuate deficit. We anticipate that this protocol will be useful for the development of glaucoma-screening paradigms.

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A neurodevelopmental case of severe impairments in mid-level vision but intact higher-level vision

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The general notion of visual development is that basic visual functions develop before more complex ones. Here, we report a neurodevelopmental case that seems to contradict this notion: A young women, LS, whom we repeatedly assessed since 2006, shows severe impairments in mid-level, but intact higher-level vision and no previous illnesses/incidents that might have caused these problems. LS is mildly hyperopic with normal oculomotor functions. Visual acuity is in the normal range as is color vision and her visual field. LS shows severe impairments in tests on contour, shape, and texture recognition as well as coherent motion (VOSP, BORB, L-POST) and peculiar eye movements when performing these tests, consummately tracing lines and outer contours with her gaze. Higher-level vision such as biological motion, object recognition based on real photographs as well as the recognition of letters and numbers is

normal, although in part effortful and slow. For face recognition, LS even demonstrates above average performance (Benton, CFMT, GFMT, Jenkins/Telling faces apart/together), e.g. 96,4% on the GFMT long version. Furthermore, she is able to identify celebrities even based on line drawings or Mooney faces faster and more accurate than controls. LS is well aware of her visual "peculiarities", her "tracking strategy" as well as her superior face recognition skills. MRI revealed no obvious brain damage. fMRI shows clear face-selective brain regions in ventral visual cortex, while neither cars nor houses elicited the typical patterns. In summary, this neurodevelopmental case provides an astonishing dissociation between mid-level and higher-level vision.

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Myopia prevalence and refractive status in primary and secondary school students in Germany

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Myopia is becoming increasingly common worldwide. This is problematic, because myopia causes a considerable individual and public financial burden, and especially high myopia can lead to serious secondary pathologies. Both myopia prevalence and the amount of current prevalence data vary substantially across the globe. A large amount of data originates from East Asia, where myopia prevalence estimates often exceed 80% for adolescents. In Europe, the prevalence is known to be considerably lower, but current data is rather sparse for all age groups. However, up-to-date information on myopia prevalence and factors associated with refractive status is important for targeted prevention and intervention, and to monitor the prevalence development. Here, we performed non-cycloplegic autorefraction on two student samples around a city in Germany. The chosen samples mark the lower and upper limits of the age span during which "school myopia" usually first appears: The younger sample included 489 primary school students (grades 3-4; mean age: 9.30 $\pm$ 0.78 years), and the older sample 1,032 secondary school students (grades 8-10; mean age: 14.99 $\pm$ 1.12 years). The older sample included the four main types of secondary schools in Germany. Preliminary analyses revealed a myopia prevalence (spherical equivalent $\leq$ -0.75D) of 8.4% in the younger sample and of 19.5% in the older sample, which is approximately comparable to other estimations for European countries. Further analyses will target factors like age, grade, school type, and gender as well as potential associations between various factors and refractive status.

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Aphantasia: How much can visual imagination influence perception of the Necker cube?

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Imagery is the ability to activately memorize perceptual representations without any sensory input. Interestingly some people are unable to evoke such visual imagery, a phenomenon that has recently been labelled "aphantasia" by Zeman (2015).

Currently it is unclear, how aphantasia is distributed in the population. Questionnaires are available but they come with problems. Keogh et al. 2018 introduced an objective behavioral measure using binocular rivalry stimuli. The basic idea was to test, whether visual imagery can bias perception of the subsequently presented rivalry stimulus. One problem of binocular rivalry stimuli is, however, the large inter-individual variability concerning appropriate stimulus parameters to balance the two perceptual outcomes.

In the present study extended the authors' seminal idea by using the ambiguous Necker cube as test stimulus. Participants were instructed to report the perceived Necker cube orientation after a period of visually imagination of either the top or the bottom cube perspective. We analysed whether the perceptual response on the Necker cube changed as a function of the previously imagined cube perspective.

Preliminary results indicate that visual imagination can have both priming and adaption effects. We further observed that the effect size differs between participants, indicating an underlying distribution. These behavioral results will be correlated with concurrently used imagery questionnaires.

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Distractor rejection in visual search in aging: Happy faces search

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Visual search becomes slower with aging, particularly when targets cannot easily be discriminated from distractors. It is unknown which distractor rejection processes underlie this age-related reaction time (RT) slowing. Several mechanisms underlying distractor rejection in visual search can be dissociated using eye-tracking: dwelling, skipping and revisiting. In the present study, we investigate the contribution of these distractor rejection processes to age-related RT slowing in a visual search task with varying target-distractor similarity. Face stimuli with neutral and happy emotional expressions are used to manipulate the task difficulty. Healthy participants (20-80 years) complete a task in which they search for a happy target face that is either similar (difficult; closed mouth smile) or dissimilar (easy; open mouth smile) to the neutral distractor faces. They complete 160 trials of which half contain a target. RT data confirms an age-related slowing, especially when the visual search is difficult because target-distractor similarity is high. The eye movement data illustrate an increase in revisiting and dwelling with age. More revisiting suggests higher uncertainty of older participants in distractor rejection. Longer dwelling on distractors suggests that older adults further spend more resources on processing distractors and accumulate more information before they decide to reject them. By contrast, it appears that the number of distractors inspected, indicated by skipping, is unaffected by age. In conclusion, our findings indicate that older adults require more time to process distractors and select distractors repeatedly before rejecting them.

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Anticipatory smooth pursuit in schizotypy

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When tracking a moving target neurotypical participants show smooth pursuit eye movements. Predictive smooth pursuit tasks (where the smooth pursuit target is not constantly visible) have demonstrated that neurotypical participants show anticipatory smooth eye movements in the direction of expected future target motion. People with schizophrenia demonstrate smooth pursuit deficits and similar findings have been observed for people with high schizotypy. Previous evidence also suggests that high schizotypics show decreased performance compared to low schizotypics in terms of predictive smooth pursuits. In the current study the length of time the smooth pursuit target was visible across six different time periods was manipulated, ranging from a typical smooth pursuit (where the target was always visible) to a time period where the target was only visible 66% of the time. Differences were found between high schizotypics and low schizotypics for normal smooth pursuit, with high schizotypics impaired, but also a difference was observed in performance across the different time periods. The results indicated that low schizotypics showed a significant decrease in performance as the target visibility decreased. However, the high schizotypic performance did not significantly decrease. The results suggest that low schizotypic participant smooth pursuit is affected by target visibility, whereas high schizotypic participant performance is less impaired. Overall these results may indicate a different mechanism for smooth pursuit in high schizotypy which is not reliant upon anticipation of target trajectory.

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Poster session 25. Motion Perception

Predictive activation of neural position representations for moving objects with and without visual attention

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Recent work has shown that neural representations of a moving stimulus are pre-activated at an expected location, ahead of incoming sensory information. This pre-activation could function to compensate for neural processing delays to allow us to localize moving objects in real-time, for example to catch a moving ball. An important open question is how such predictive mechanisms are related to visual attention, which plays an important role in selecting sensory information in the world around us. We addressed this question by investigating the effects of attention on predictive pre-activation of position representations in an apparent motion paradigm. Electroencephalography (EEG) data was recorded while participants (N= 33) viewed two apparent motion stimuli move simultaneously along independent circular paths – attending to one stimulus and ignoring the other. Multivariate pattern classifiers were trained on individual presentations at each of the possible object positions, and then tested on both attended and unattended motion sequences. Preliminary analyses indicate that it is possible to decode the anticipated future position of a moving stimulus for both the attended and unattended motion sequence, indicating that attention is not necessary for motion prediction. Additional analyses are currently being conducted to examine whether attention might nevertheless have a modulatory role in the pre-activation of position representations.

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Tracking motion integration signals in early visual areas

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Little is known about the functional and perceptual role of feedback (FB) signals in cortico-cortical networks. There is empirical evidence that complex pattern motion is processed in human Medial Temporal complex (hMT+) although perceptual motion signals can be detected in early visual areas V1 and V2. Here, employing bistable moving plaids and functional imaging we investigated the nature of the FB signal between hMT+ and areas V1 and V2. Subjects viewed an ambiguous plaid composed of two superimposed moving gratings. This stimulus resulted in spontaneous switches in perception between two stable interpretations, component motion or pattern motion. In a 3T MRI scanner, thirty-four participants reported perceptual transitions between the two states, while fixating a central cross. Direction-tuned populations of voxels in V1 and V2 displayed a strong perceptual modulation of activity, showing stronger activity for either the component or pattern direction, depending on the perceptual state. These results suggest that perceptual state is fed back to V1 and V2, supporting hierarchical models of perceptual inference. Future research will aim to unravel the interaction of the FB signals with area V1, by assessing the laminar activity profiles of the motion signals conveyed, using ultra-high resolution fMRI, thereby informing on the role of FB pathways in hierarchical processing.

Supported: The Netherlands Organisation for Scientific Research (NWO) and the French National Research Agency (ANR) (LabEx Cortex, Dual_Streams).

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Does Global Context Affect Memory for Position in the Onset Repulsion Effect?

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The onset repulsion effect (ORE) refers to the tendency to misremember the first appearance of a moving object as being back behind its true onset position, that is, in a direction opposite to the path of motion (Actis-Grosso & Stucchi, 2003; Thornton, 2002). While the ORE has been replicated many times, the underlying cause for such a backward shift is still unclear. The present study was designed to (i) test whether the ORE can be observed in an online environment, and (ii) examine whether the global context of a motion event (e.g., the number of motion segments or the presence/absence of shape-cueing) modulates patterns of responding. In three separate experiments, observers were asked to watch a smoothly moving target and to subsequently indicate its starting, stopping (and if relevant) turning points. In some conditions, shape cues were provided via both instructions (e.g., complete the sides of the triangle/rectangle) and visual feedback. In all conditions a robust ORE was observed, indicating that the effect can be observed in an online environment, where viewing conditions are not controlled. However, the global context of the motion event had very little influence on the pattern of error. This contrasts with Representational Momentum – the tendency to misremember the stopping point of an event –which is known to be modulated by context (Freyd & Finke, 1984; Vinson & Reed, 2002). The current findings suggest that the ORE is likely determined by low-level perceptual mechanisms, with less susceptibility to higher-level contextual influences.

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Deformation detection and constancy across optical material and illumination variations

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Perceptually relevant information for detecting dynamic changes in the geometry of a 3D object (i.e., shape deformations) is contained in the optical flow patterns. It is far from a trivial problem for the visual system to robustly isolate the changes in optical flow caused by shape deformations across a diversity of optical materials, since glossy materials produce drastically different optical flow patterns compared to, for example, transparent materials. We studied deformation perception with rotating infinite-knot shaped stimuli, rendered with four optical materials (matte, glossy, mirrored, and transparent), under three illumination conditions. In addition to the side-view condition we used previously (VSS2022), we tested a condition where the rotating object was viewed from the direction 45° above the side-view condition. Deformation detection (rigid vs. deformed discrimination measured by 2-IFC, n=25)

was found to be robust in general. There were slight effects of optical material variations and no effect of changes in illumination. The performance was reduced in the 45° condition, possibly due to the weakening of a 2D silhouette cue, but still stable across materials and illuminations. A binomial GLM was able to perfectly detect deformations using simple predictors based on the ground-truth motion flow, however, an identical model was not able to detect deformations using the optical flow parameters extracted by RAFT (optical flow DNN). Despite the optical effects of material and illumination obfuscating deformation cues in the optical flow, the human visual system can robustly perceive deformations by discounting these effects, at least partially.

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Is Representational Momentum modulated by object complexity?

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Representational Momentum (RM) refers to the tendency to misremember the stopping point of an event as being further forward in the direction of motion or change (Freyd & Finke, 1984). The current work explored whether estimates of the final position of object features are influenced by the global complexity of the entire object. On a given trial, the display consisted of either 1, 5, 10, 15, 20 or 25 black dots (5 pixel diameter) on a grey background, spread equally around the edges of a central (50 pixel diameter) non-visible circle. At the start of each trial, one dot was selected as the target dot and was highlighted in blue. The task was to explicitly track this target dot and to remember its final location, ignoring other aspects of the display. To initiate movement, observers clicked within a designated central area. After a random delay, the colour cue changed to black and all dots began to smoothly expand away from the centre at the same fixed speed (50 pixels/s). At a randomly varied distance from the centre, all dots vanished together. The task was then to click the mouse in the exact remembered final position of the target dot. RM effects were found in all conditions, but varied as a function of object complexity. There was an increase in the size of the forward shift up to approximately 15 dots, but a decline thereafter. Possible causes for this pattern, including implied complexity/mass, divided attention, and distractor proximity will be discussed.

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Offset localization of dynamic stimuli: Can speed characteristics of the experimental context influence the Representational Momentum Phenomenon?

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Representational Momentum (RM) is a robust phenomenon in which the final location of an (implied) motion sequence is systematically overestimated in motion direction. Recently, a new theory was proposed to explain this (and related) phenomena, the speed prior account (Merz et al., 2022). This account proposes that a mismatch between a priori speed expectations and actual stimulus speed leads to localization biases such as the Representational Momentum phenomenon. Therefore, this experimental series analyses perceptually identical trials in different experimental contexts, that is, intermixed with random motion stimuli, resulting in different speed characteristics of different experimental contexts. In our data, a strong influence of experimental context as observed, and subsequent follow up experiments indicate that global context (proportion of motion and control trials within one experimental block), not local context (trial N-1), is the driving factor behind this influence. That is, a motion sequence for which a robust RM phenomenon is observed when presented in isolation, decreased or even no overestimation is observed when intermixed with random-motion stimuli. The results challenge classical theoretical framework in the representational momentum literature, but are in line with theoretical frameworks describing speed expectation as an important underlying factor for the perception of moving stimuli.

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Modulation effect of preceding motion stimuli on resolution of motion rivalry

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Resolution of binocular onset rivalry can be modulated in a feature-specific fashion by presenting a preceding stimulus (e.g., Abe et al., 2011, JoV). This study investigated how the resolution of rivalrous moving test stimuli (leftward- vs. rightward-moving gratings) is determined by manipulating the motion direction of the preceding stimulus.

Specifically, we asked whether rivalry resolution is modulated by physical motion of the preceding stimulus separately presented to each eye (component motion) or binocularly-integrated pattern motion of the two (pattern motion). Under the congruent component-motion condition, the left and right preceding stimulus was a rightward and upward moving grating, respectively, and thus the motion direction of one preceding stimulus was the same as that of one test stimulus. However, the two preceding stimuli were binocularly integrated and perceived as a right-upward moving pattern. Under the congruent pattern-motion condition, the left and right preceding stimulus was a right-upward and right-downward moving grating, respectively, and the preceding stimulus was perceived as a binocularly-integrated rightward moving pattern. Results showed that under both conditions the leftward-moving test stimulus, which had the opposite direction to the preceding stimulus, was perceived more frequently. Moreover, this repulsive modulation of motion rivalry was stronger when both preceding stimuli were rightward-moving gratings (control condition). These results can be understood in terms of the effects of the component motion; the preceding stimulus presented to each eye separately exerted modulating effects on resolution of motion rivalry. The resolution seemed to be affected little, if any, by the perceived pattern motion.

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Environmental cues correct heading biases from limb articulation.

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Self-motion generates a pattern of expanding visual motion called optic flow. Heading estimation from optic flow analysis is accurate in rigid environments but becomes challenging when other walking humans populate the scene. In particular, their limb articulation introduces heading biases. To what extent do environmental cues correct such errors? We investigated the interaction between biological motion and environmental cues.

We simulated self-motion along a straight path towards a group of point-light walkers, collectively facing to the left or right. One group of participants (n = 24) saw the walkers placed in an experimental world absent of depth and environmental cues. The second sample (n = 30) encountered two scenes. The first arranged the walkers in different depths to induce motion parallax. The second scene combined motion parallax with a visible ground plane. Subjects sketched their perceived path to their perceived heading.

Without environmental cues, participants consistently drew a curved path. Their heading estimates were inaccurate. Motion parallax alone did little to change this misperception. But the ground plane diminished the perceived curvature and reduced heading estimation variance. We reason the visible ground plane combined with motion parallax solves path ambiguity. As outcomes, heading estimation becomes more accurate, and observers correctly perceive their traveled path as linear.

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Heterogenous center-surround antagonism in translational, radial and circular motion processing

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Visual motion processing shows center-surround antagonism. Previous studies usually used various sizes of drifting Gabors to measure the exposure duration for translational motion. However, less is known about whether center-surround antagonism is a general mechanism that takes place in the processing of radial and circular motion, which is believed to be processed in different cortical areas. We adopted three types of stimuli, including Gabors, sinusoidal circular gratings and sinusoidal radial gratings that produced translational, radial and circular motion, respectively. In each trial, participants were required to determine the direction of motion (left/right, inward/outward, counterclockwise/clockwise). Four stimuli sizes (1.8o, 3.6o, 7.2o, 14.4o) and four contrast levels (2.5%, 10%, 40%, 80%) were introduced, and the exposure duration threshold was measured. Results showed that at a high contrast level, duration thresholds increased with an increase in the size for translational and radial motion, whereas at a low contrast level, the duration thresholds decreased along with the size. In addition, the suppression index, which is defined as the difference in the threshold between the large size and the small size, was different for translational and radial motion. For circular motion, the duration thresholds decreased with an increase in size and contrast. Our experimental results indicated that the center-surround interaction took place during translational and radial motion processing but not during circular motion processing. Different levels of motion processing might involve different spatial center-surround antagonism.

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Re-examining the link between alpha band oscillation and illusory jitter perception – an EEG study

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When two edges with different apparent speeds move rigidly, as a combined stimulus, the edge with a lower speed appears to jitter. The perceived jitter frequency is approximately 10 Hz and is invariant to change in stimulus form and speed. Prior Magnetoencephalography (MEG) studies have shown an alpha band amplification during illusory jitter perception and an association between peak alpha frequency and illusory jitter frequency. Recently, we observed a correlation between participants illusory jitter frequency and their processing rate in the well-established Motion Induced Position Shift task, which implies a common and periodic motion prediction mechanism underlying those two tasks. Here, we re-examined the link between alpha oscillation and illusory jitter perception using an Electroencephalogram (EEG) technique. We found an alpha power enhancement during the illusory jitter display in comparison to a physical jitter display. However, we did not find a correlation between illusory jitter frequency and peak alpha frequency measured during resting-state conditions (prior to the task) and during the task (prior to the illusion onset). Furthermore, we did not find a correlation between spontaneous variation of the alpha band power and instantaneous changes in the perceived jitter frequency. These findings confirm a link between brain alpha oscillation and illusory jitter perception but leave open the question of what determines this association between alpha band frequency and the processing speed in the jitter illusion and what its role might be in motion-based visual prediction.

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The strength of the interaction between fine and coarse scales in motion discrimination is size tuned

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Psychophysical research shows impairment in motion discrimination of high spatial-frequency stimuli when is added to a static low spatial-frequency pattern, and facilitation for a moving low spatial-frequency stimulus added to a static high spatial-frequency component (Serrano-Pedraza et al.,2013JoV). Although the interaction between fine and coarse scales depends on the size and contrast (Serrano-Pedraza & Derrington,2010,JoV), the effect of larger sizes than 4deg of diameter is unknown. Here, we test eight diameters: 1,2,3,4,5,6,7 & 8deg, measuring duration thresholds in a motion discrimination task. The stimuli were vertical Gabor patches of 46% contrast. Four conditions were tested, simple stimuli 1c/deg moving and 3c/deg moving, and complex stimuli, 1c/deg static added to a 3c/deg moving (1s+3m), and 1c/deg moving added to a 3c/deg static (1m+3s). In total, we tested 32 combinations of conditions and sizes. Our results show that duration thresholds for the condition 1s+3m increase with size up to 3-4 deg and then, decrease for larger sizes (6-8deg). However, for the condition 1m+3s, we found the opposite behavior: duration thresholds decrease with increasing size up to 2-4deg and then increase for larger sizes. The strength of the interaction was estimated with an interaction index, subtracting the duration thresholds (in log-units) of the complex minus the simple stimulus. The interaction index for 1s+3m has a band-pass shape when represented as a function of size, with the maximum around 3-4deg of diameter, and for 1m+3s shows a notch-band shape. Our results show, for the first time, that the interaction between scales is size tuned.

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Poster session 26. Scene Perception

Scene context-driven prediction of object transformations in visual cortex

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As we move through our environment, our viewpoint on the objects in a scene changes continuously, but this change is consistent across the objects and the background of the scene. Scene context thus provides powerful cues to predict how objects will look from a new viewpoint, even when objects are temporarily invisible, for example due to occlusion. Here, we investigate whether human observers dynamically predict the appearance of objects based on the surrounding scene, and how such predictions affect the processing of these objects in visual cortex. In a series of online behavioral experiments (N=152), we found that participants exploited scene information to predict the appearance of three-dimensional objects from novel viewpoints: when objects, after being occluded, reappeared rotated coherently (rather than incoherently) with the surrounding scene, participants were better at performing an orthogonal visual task on them. This effect persisted even when coherent object views were relatively unlikely to appear (25% of trials). In an fMRI study (N=34), we found that this behavioral difference was reflected in early visual cortex: linear classifiers trained to decode the proximal shape of the object after it reappeared were more accurate when this shape was consistent with scene-driven expectations. These results indicate that scene context informs predictions of object transformations, and that these predictions sharpen low-level representations in visual cortex.

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The effects of recent event knowledge and semantics in the guidance of fixations on scenes

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A person viewing a real-world event typically accesses two sources of non-visual information: knowledge of the preceding events and semantic knowledge about the objects commonly found in a given scene (e.g., toaster in a kitchen). We investigated how these two types of knowledge jointly guide human gaze. We recorded eye movements of 48 participants viewing 80 sequences of movie frames. Each sequence showed an unfolding of events and ended with a 'critical frame' that depicted either a natural continuation of these events (Expected condition) or an event unrelated to them (Unexpected condition). We used GloVe, a computational linguistic tool, to calculate 'semantic similarity scores' for objects within critical frames. These scores measure the semantic similarity between an object and all other objects in the scene. We analysed the number of fixations per object and found that participants made more object fixations in the Unexpected condition (vs. Expected; $p < .001$), i.e., when their knowledge about past events was irrelevant. Moreover, in both conditions, objects with low semantic similarity scores attracted more fixations than objects with high scores ($p = .026$). Interestingly, this effect was weaker in the Expected condition ($p = .014$), which suggests that relevant knowledge about past events available only in the Expected condition modulated the effect of the semantic scene knowledge. Taken together, we demonstrate that knowledge about recent events and semantic scene knowledge interact when guiding human gaze.

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Pictures of natural environments selectively modulate brain activity independently from low-level visual features and subjective perception: An ERP study

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The cognitive mechanisms modulating human's general preference for natural over urban environments are not fully understood. The present research aims to study, using psychophysiological methods (EEG), the features of natural environments that may be linked to human preference, linked to cognitive and attentional load linked to the exposure to different types of environments. Four experiments were performed using EEG, and a visual serial presentation paradigm. Each experiment aimed to understand if low-level (visual) or high level (cognitive) mechanism may be responsible for the modulation of attentional demand for natural settings (vs. urban ones) reported in the scientific literature. The first two experiments featured three categories of pictures: natural, urban, and geometric fractals. Experiment 1a utilized images equalized only for luminance and contrast, while in experiment 1b the images were also equalized for spatial frequency. In experiments 2a and 2b, the images selected displayed instead of the fractal images, images of libraries (generally a restorative man-made environment). In experiment 2a the images presented were equalized only for luminance and contrast, experiment 2b featured images obtained from an algorithmic extraction of shapes from the images used in experiment 2a. In experiments 1a, and 1b, participants rated natural images as more relaxing than the other image categories. Brain data showed that early attentional processes (EPN) were suppressed for natural images vs. the others. In experiments 2a, and 2b, participants rated library images as more relaxing than nature ones. Despite the subjective evaluation, nature images selectively modulated brain activity.

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Expectations based on prior knowledge sharpen the perceived visual signal as its reliability decreases.

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Predictive coding theories of visual perception postulate that predictions based on prior knowledge modulate information processing by sharpening the representation of expected stimuli in visual cortical areas. Our recent findings showed that this is also associated with increased perceived sharpness of expected visual stimuli According to recent accounts of the predictive processing scheme, this sharpening mechanism would predominate when sensory signals are noisy and ambiguous. Our study addressed this hypothesis by investigating whether the influence of expectations on the perceived sharpness of scenes increased as the reliability of the visual signal decreased. We used a perceptual matching task in which participants were presented with two blurred images depicting two versions of the same scene and asked to adjust the blur level of one scene to match that of the other one. We manipulated the initial blur level of scenes (i.e., signal reliability) and the predictability of scenes which could be either upright (i.e., compatible with expectations)

or inverted (i.e., incompatible with expectations). Results revealed that at an equal level of blur, predictable scenes were subjectively perceived as sharper than unpredictable ones and this difference increased as signal reliability decreased. However, this effect stopped increasing when signal reliability was at the lowest. Our results support predictive coding theories postulating a larger influence of predictions on perception when the signal is noisy. When sensory signals are too noisy, predictions may however be too diverse and therefore too coarse to further sharpen the stimulus representation.

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Large objects prime visual representations of space

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Large and stable objects, such as buildings and furniture, activate scene-selective brain regions in visual cortex. One interpretation of this finding is that large objects prime representations of local space. However, several alternative interpretations exist, including that it reflects shared visual features across buildings and scenes (e.g., rectilinearity, cardinal orientations). Here, we used closely matched images of buildings and boxes to provide evidence for the space-priming hypothesis. In a behavioral study (N=26), we find that isolated images of buildings induce a Ponzo illusion: lines that were presented above buildings were judged as longer than lines presented below buildings. This illusion was not evoked by visually-matched boxes and was nearly as strong as the classical illusion evoked by converging lines. Next, we used EEG to test whether buildings (versus boxes) evoke scene-selective neural responses. Critically, if buildings prime space, the scene-selective response evoked by buildings should be delayed relative to the response evoked by scenes. During EEG recording, participants (N=32) viewed isolated images of buildings, boxes, scenes, and chairs. Multivariate decoding analyses across posterior electrodes allowed for distinguishing visually-matched buildings from boxes relatively late in time, from around 400 ms after stimulus onset. Importantly, in a cross-decoding analysis, this late building-selective response generalized to distinguish scenes from chairs from as early as 200 ms after onset, indicating that buildings activated the visual representation of scenes. Taken together, these results provide evidence that large objects prime visual representations of local space.

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"Get your room done" revisited: Scene clutter affects the spatial distribution of attention at encoding but not performance at retrieval in school-aged children.

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Every day, children are exposed to visually rich, oftentimes cluttered, environments. Although previous research has demonstrated that a single exposure to disorganized environments degrades children's cognitive performance, little is known about the effects of repeated exposure to such environments on learning and memory.

To examine this, children aged 8-12 years old completed two tasks: 1) a search-based learning task, during which they had to detect and memorize the location of a target superimposed on images of scenes (cluttered vs. uncluttered) across four repeated blocks while their eye-movements were recorded, and 2) a cued recall task, in which they had to recall the target locations in the previously-studied scenes.

Behavioral results showed that, in the learning task, children detected the target faster in uncluttered than in cluttered scenes across all blocks, indicating that clutter degraded search times and this effect remained even after repeated exposure to the scenes. Furthermore, eye-tracking data showed that attention allocation was more diffused in cluttered than in uncluttered scenes, and this pattern persisted until the last block, despite getting smaller. In the cued recall task, children recalled the target locations with similar precision across both clutter scenes.

Overall, our findings suggest that even though clutter influences children's learning efficiency and eye-movement patterns even after multiple exposures to the same scenes, its impact does not transfer to long-term memory performance for spatial targets once these are learned. These results highlight that the effects of clutter on cognition might not be as broad as previously thought.

Acknowledgement: this project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Innovative Training Network, Grant Agreement No 813546

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Tafereel

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"Tafereel" is a Dutch word that has a complex meaning involving aspects of "scene," "depiction" and "stage."

It is formally at least partly captured by scenography, which maps the infinite frustum of visual space on a finite cuboid.

As the box depth is set to zero one obtains a perspective rendering.

An infinitesimal box depth yields a "thick," or "enchanted" picture.

It retains the depth relations, which are lost in the "disenchanted" perspective rendering.

The formal account of this picture box is the geometrical scaffold of pictorial space.

We show applications from the visual arts.

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Synaesthesia and its relation to social and sensory aspects of autism

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In synaesthesia, individuals experience additional sensations for specific sensory input, e.g., seeing colours for letters. Synaesthesia occurs roughly five times more often in individuals on the autism spectrum, but it is not known how synaesthesia affects autistic individuals. We set out to discover whether having synaesthesia in addition to autism coincides with the presence of specific autistic traits. Because of synaesthesia's perceptual and sensory characteristics, we hypothesized that the presence of synaesthesia would be associated with stronger sensory alterations in autism, such as increased reports of hypersensitivity to sensory stimulation, and increased scores on the Autism Spectrum Quotient (AQ) subscale related to perception (Attention to Details). Both individuals on the autism spectrum with synaesthesia (N=25) and individuals on the autism spectrum without synaesthesia (N=36) completed a part of the Glasgow Sensory Questionnaire (GSQ), three subscales of the Dutch AQ, and a synaesthesia consistency test. Data collection is still ongoing, but preliminary results show that the synaesthetes scored significantly higher on the GSQ questions, indicating stronger hypersensitivity than the non-synaesthetic autistic individuals. A repeated measures ANOVA with the factors of AQ subscale (Social Skills, Communication, Attention to Details) X group (synaesthesia present/absent), showed a significant subscale by group interaction: synaesthetes scored numerically lower for Social Skills and numerically higher for Attention to Details than the non-synaesthetes, although follow-up tests comparing subscale scores between groups were not significant. The preliminary results suggest that individuals on the autism spectrum with synaesthesia experience more hypersensitivity than individuals on the autism spectrum without synaesthesia.

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Two temporal frequency mechanisms in frontoparallel cyclopean motion revealed by analysing individual differences.

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The study of the underlaying mechanisms in stereovision is mainly limited to static stereopsis (Howard & Rogers, 2012). Masking experiments, using vertical and horizontal sinusoidal depth corrugations, have suggested the existence of more than two spatial-frequency disparity mechanisms (Serrano-Pedraza et al., 2013). This result was also confirmed through an individual differences approach (Peterzell, et al., 2017). Using factor analytic techniques, we want to investigate the possible existence of independent temporal-frequency disparity mechanisms in frontoparallel cyclopean motion. To construct cyclopean motion, we used sinusoidal disparity corrugations obtained with random gaussian-dots stereograms that changed every frame at 120Hz. Thus, no luminance motion was present monocularly, only the sinusoidal corrugation was moved. We measured disparity thresholds for detecting the correct direction of motion of vertical (up-down) and horizontal (left-right) sinusoidal corrugations of 0.4 c/deg drifting at 0.25,0.5,1,2,4,6, and 8Hz. In total we tested 34 participants. Results show a mild orientation anisotropy with higher thresholds for vertical corrugations. Disparity thresholds as a function of temporal frequency are almost constant from 0.25 up to 1c/deg and then they increase monotonically. Principal component analysis uncovered two factors that accounted for 72% of the variability. Varimax rotation showed that one factor loaded from 0.25 to 2Hz and a second factor from 4 to 8Hz. Direct Oblimin rotation indicates a moderate intercorrelation of both factors. Results suggest the existence of two moderately interdependent temporal frequency mechanisms in cyclopean motion (slow and fast) like those found in the luminance domain suggesting a similar low-level motion mechanism for both domains.

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Additivity of grouping by proximity and luminance similarity: General results and individual differences

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One of the fundamental ideas of Gestalt Psychology is that "the whole is more/different than the sum of its parts". This statement suggests that the construction of a Gestalt results in properties that cannot be explained by looking at the features of the separate elements before they are organized. However, this idea was seriously debunked by Kubovy and van den Berg (2008) who revealed that the strength of grouping within a dot lattice results from an additive integration of the separate grouping principles at play (proximity and luminance similarity). Although innovative, their conclusion was based on effects at group-level, as most Gestalt research, and could therefore be the result of averaging over different types of observers. To explore this possibility, we replicated the original study by Kubovy and van den Berg but added an individual differences approach to the group-level analysis. For all individuals, we observed that both grouping principles interacted additively again. Although all observers showed grouping by proximity, some observers did not group by luminance similarity, however. In addition, a correlation between both grouping principles was found, which suggests stable individual differences in the general strength of grouping. To assess the reliability of these individual differences and to get a quantification of the weight of each principle, we are testing a few participants longitudinally in multiple sessions of the original task and we will model the results for each participant individually.

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Dwell time preferences for gaze-based object selection of different object types vary with age

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Onscreen gaze-based object selection or activation typically requires a dwell time: a minimum amount of object gaze time necessary for its selection to occur. Dwell time is often uniformly set and varies greatly with the type of user interface. Finding a suitable dwell time for individual users, however, is important for any interface that relies on eye tracking and gaze-based input. Short dwell times are prone to the Midas touch problem, i.e., the unwanted selection of an object by unintendedly gazing upon it in search for the intended object. Long dwell times, by contrast, may lead to a sluggish interface performance and user dissatisfaction. Our recent research has shown that gaze-based selection of 4-object sequences consisting of either visual icons, dot patterns, or alphanumeric objects occurs most efficiently with a dwell time of about 600 ms for relatively young users. Here we show that, for these three object types, overall gaze-based selection time and object dwell time preferences markedly differ between age groups. Younger users (<35 years of age) indeed require less selection time, with fewer selection mistakes, than users of 36-55 years of age or of 56-75 years of age. The elderly group also prefers a longer object dwell time of about 800 ms, for any object type. Individual dwell time settings thus seem necessary for different age groups, but not for different object types.

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Differences in susceptibility to visual illusions between trainee radiologists and general population

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Visual illusions offer a unique insight into the mechanisms behind perception and potentially insight into the visual processing of complex patterns in radiological images. Radiological examination error rates have an error rate as high as 33% of the time. Given the difficulty of medical image interpretation and the societal costs of errors made by radiologists, a large body of research has investigated how expertise in interpreting medical images develops. Previous studies have focussed on the radiologists' visual search abilities with evidence of domain-specific expertise that do not extend to other non-domain search tasks. This study aimed to test whether the perception of specific visual illusions is shaped by visual expertise. 39 young adults and 10 trainee radiologists were tested on a battery of visual illusions using a two-alternative forced choice paradigm. Radiologists performed significantly better that non-experts on their size discrimination ability on the Ebbinghaus illusion, while non-experts performed significantly better than radiologists on the Brightness illusion. The difference between radiologists and non-experts on the susceptibility to the Ponzo illusion was close to significance ($p = 0.051$), favouring radiologist over non-experts. Radiologists performed significantly better than non-experts on the luminance test. Significantly better performance on the luminance task and the Ebbinghaus reveals that radiological expertise is

associated with enhanced visual skills in specific perceptual tasks in comparison to the general population.

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Dependence or independence of visual object recognition mechanisms

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Visual object recognition could rely upon dissociable or shared mechanisms. Domain-specific accounts argue that object categories like words and faces are processed by largely independent mechanisms. On the other hand, some accounts assume that face and word recognition share or even compete for the same cortical resources. We assessed performance with faces, houses, and pseudowords in a task where either features or configuration of features were systematically varied/manipulated (N = 101). On each trial of the task, a sample (unfamiliar face, unfamiliar house, or pseudoword) appeared at screen center followed by match and foil images displayed simultaneously to the left and right of screen center. The match image was identical to the sample image, but the foil image was different either featurally or configurally. To estimate the separability of visual object recognition mechanisms, we used representational similarity analysis (RSA) where a correlational matrix for accuracy (reference model) was compared to predicted data patterns. By means of Bayesian regression, we found that a face specialization model – where processing of faces differs from processing of both words and houses and where processing of houses and words does not differ – provides the best solo account of the results. This suggests that faces are processed in a specialized manner in this task while objects and words rely on common processes.

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Text as information gain to reduce visual indeterminacy

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Indeterminacy characterises images to which viewers experience difficulty in assigning a coherent spatial interpretation, accompanied by a sense of curiosity to solve a 'visual puzzle' (Pepperell, 2011). According to the prediction error account of Van de Cruys and Wagemans (2011), 'artists attempt to strike optimal balance between predictability and surprise'. In the tradition of Western religious art, text has been used to reduce uncertainty, suggesting the viewer the 'right' way of interpreting an image (Heal, 2017; Koerner, 2003). We used a set of 30 indeterminate paintings by Robert Pepperell to test if different titling (religious, secular and 'untitled') influenced viewers' experience. Following the methodology developed by Van de Cruys et al. (2021), we asked participants (N=101) to rate artworks on a series of experimental variables, including liking, curiosity, perceived indeterminacy, 'Aha' experience, and liking after revealing the artwork's title (curiosity relief). The results replicated the main findings of the original paper by Van de Cruys et al. (2021), except for the negative relationship between confidence and curiosity, which was positive in our study ($R = .19$, $p = < .001$). Moreover, religious participants reported significantly stronger 'Aha' experiences with religious over secular titles, compared to non-believers ($\beta = 0.16$, $t(3015) = 2.18$, $p = .03$). Our results support the idea advanced by Van de Cruys & Wagemans (2011), that uncertainty reduction plays an important role in perception of art. Future studies might compare Pepperell's artworks to other indeterminate images (e.g. Mooneys) to further investigate the relationship between confidence and curiosity.

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Lower sensorimotor serial dependences in high versus low autistic tendency

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Besides social and communicative deficits, individuals with Autism exhibit a weaker prediction of action consequences. Optimal sensorimotor control is achieved by combining noisy sensory information during saccades and prior knowledge. The integration between priors and sensory evidence has reported to be affected in ASD. Here, we implemented a n-back experiment to investigate serial dependence between post-saccadic errors and visual localization accuracy in healthy adults with various degrees of Autistic Traits. Participants executed a saccade in trial n¬–1. During the saccade execution, the target was displaced to the left or to the right. In the subsequent trial n, participants were asked to localize a briefly flashed target with a mouse pointer while keeping gaze directed to the fixation point. We observed that the size of the post saccadic error in

trial n−1 biased where subjects localized a target in trial n, and that the slopes of this relationship were correlated with the autistic symptomatology, being higher for low autistic traits. Moreover, only in the low AQ subsample, post-saccadic errors in the preceding trials affected the saccade landing in trial n−1, but not the visual localization, suggesting a strength in serial dependency between saccade landings. Altogether, results show that participants scoring lower on the questionnaire were more susceptible to the influence of prior stimuli. This finding suggests that these individuals update their perceptual representations according to prior context, while individuals with higher degree of autistic traits have a reduced adaptation to recent sensory stimuli.

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How age affects the preparation effects under cross-modal switching: Evidence from behavioral and ERP measures

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The present study investigated the effects of aging in preparatory processes when attention was switched between different sensory modalities. The cued attention-switching paradigm was conducted and the behavioral performance, along with event-related potentials (ERPs), were measured. The lateralized visual stimuli and auditory targets were presented simultaneously, and the participants had to judge whether the relevant modality target appeared on the left or right side (i.e., spatial location task), based on a modality cue (either visual or auditory). The cue-to-target interval was manipulated to investigate the preparation effect. The behavioral performance showed that the switch cost, defined as the performance differences between switch modality trials and repeated modality trials, benefitted from the preparation process for both younger and elderly participants, while the preparation benefits for the elderly were larger under the visual modality. The cue-locked ERP switch cost waveforms showed that the amplitude of N1 (50–150ms) was larger for the younger than for the elderly participants in the auditory trials under both short and long cue-to-target intervals. The stimulus-locked ERP switch cost waveforms in P2 (150–250ms) were similar for younger and elderly participants under long cue-to-target interval trials, while the polarity differed for visual trials between the elderly and younger participants at short cue-to-target interval trials. Our experimental results demonstrated no age differences in the behavioral effects of preparation, but elderly people might use different strategies to perform the task, such as relying on memory retrieval for the cues.

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Training individual differences in color qualia

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One of the most intriguing philosophical questions in neuroscience concerns the neural basis of conscious experience. Recent studies suggest that training novel qualia might offer an opportunity for neuroscientists to trace the formation of first-person experience in neurobiological terms. Hence, the primary goal of the current study is to corroborate previous findings that (color) qualia can be acquired by means of extensive training (i.e., reading books with colored letters). In addition, the study addresses how novel qualia affect higher cognitive functions, such as early visual memory. In the current study, the reading-in-color method is used to train color qualia in a pre- versus post-training fMRI experiment (N = 50). Within color-selective brain regions, we expect the representations (at the voxel-level) of the achromatic trained letters (e.g., 'a') to become similar to the representations of the corresponding trained colors (e.g., red) due to training. Finally, we will test the hypothesis that the nature of the trained color qualia will predict both the type and degree of the newly formed occipito-parietal binding mechanisms, using dynamic causal modeling methods. From a neuroscience perspective, our findings will provide insights into how newly formed representations are integrated in the brain through environmental exposure, underscoring the experience-dependent nature of visual perceptual reality that is unique to each individual.

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01 September 2022

Symposium 11. Eyeballing the visual field: eye-tracking- and pupillometry-based alternatives for visual field assessment

An introduction to visual field assessments using standard automated perimetry and continuous visual stimulus tracking

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Perimetry is the systematic measurement of the visual field (VF). It is an essential tool in ophthalmic care and visual rehabilitation to detect impaired function of central and peripheral vision. The current gold standard is standard automated perimetry (SAP) during which stimuli of different luminances are presented at various locations in the VF while the participant fixates a central target and presses a button when a stimulus is seen. Performing SAP thus requires understanding fairly complicated task instructions, multi-tasking, and prolonged focused attention from the participant, making the test unsuited for several groups, such as elderly individuals. As an alternative, studies have shown that eye movements can replace manual responses and make obtaining VF assessments easier and more comfortable.

Recently, we have shown that in healthy observers, continuous stimulus tracking performance (measured as the agreement between gaze and stimulus movements) depends highly on the stimulus contrast. However, it is unknown how VF defects (VFD) affect tracking performance at different stimulus contrasts and whether VFD severity can be determined from tracking performance. Here, we studied continuous stimulus tracking in glaucoma patients at three contrast levels. Preliminary data show that VFD severity strongly influenced tracking performance, where less severe VFD only influenced tracking performance at the lowest contrast level (40%), but severe VFD influenced performance even at the highest contrast level (640%). Overall, the data thus indicate that it is possible to differentiate between VFD severities in glaucoma with continuous stimulus tracking, suggesting important opportunities for optimizing this perimetric approach.

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Exploring the potential of portable visual fields assessment using Virtual-Reality and eye movement based perimetry

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Although standard automated perimetry (SAP) is considered the gold standard for assessing visual fields (VF), it has some shortcomings that limit its use in different clinical groups. SAP requires stable fixation, periodic motor response and prolonged attention. Moreover, the associated equipment is bulky and necessitates the chin and head to be stable throughout the procedure. Virtual reality (VR) has become increasingly popular in ophthalmic diagnostics due to its portability, precise control over experimental settings, and freedom of head movement. So, would eye movements (EM) in a VR-based framework be an effective and intuitive way to screen for VF defects? To this end, we asked 15 control participants naïve to SAP and 15 participants with a glaucomatous or neuro-ophthalmic VF defect to perform three variants of perimetry in a counterbalanced fashion: (1) VR-based perimetry based on continuous visual tracking on a VR headset while their EM were recorded, (2) the preceding approach but using a screen and remote eye tracker and (3) SAP. We found that the VR-based approach 1) could distinguish participants according to their oculomotor characteristics, 2) was similar in performance to the screen-based approach in terms of quantifying the spatio-temporal properties of EM, and 3) adjudged to be more user-friendly compared to the screen-based approach and SAP. These results are an encouraging first step towards creating a portable yet comprehensive visual field assessment framework using VR and EM-based perimetry. Such a user-friendly approach can complement existing perimetric techniques in ophthalmology.

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Recent developments in pupil perimetry

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Pupil perimetry (PP) is a diagnostic visual field test that measures sensitivities to light stimuli presented across the visual field. The amplitude of a pupil orienting response (or light reflex) to a bright stimulus onset represents visual sensitivity as a continuous measure. Relatively weak amplitudes of responses to either local or global stimuli can indicate impaired visual processing at any possible stage of the visual hierarchy, both early in the retina and later in the (extra)striate cortex. As an alternative to subjective forms of perimetry, during which observers introspectively report whether (or when) they saw a stimulus, PP allows a more objective assessment of visual field sensitivities, making it especially suitable for testing children and stroke patients that have difficulty reporting perception. In this talk we present recent developments in PP, including (i) improvements to stimulus presentation paradigms to achieve higher diagnostic performances, (ii) state-of-the-art apparatus, (iii) assessments of cerebral visual impairments, and (iv) applications in pediatric ophthalmology. The advances in PP have resulted in promising performance outcomes when it comes to mapping large scotomas in patients and detecting subtle differences in visual sensitivities between visual field quadrants. All these scientific efforts are now starting to accumulate in the formation of a solid methodological basis for future research into the plasticity of healthy and impaired visual systems of both young and elderly populations.

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What's on TV? Detecting visual field loss using natural eye-movement scan-paths?

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Purpose: Can natural eye-movements be used to detect glaucomatous visual field (VF) loss?

Methods: In three studies, natural eye-movements were recorded while viewing movies or still-images. In Study 1 [Crabb et al. 2014 PMID: 25429267], machine learning was used to discriminate glaucoma patients (n=44) from healthy peers (n=32). In Study 2 [Asfaw et al. 2018 PMID: 29971443], eye-movement parameters were compared between both eyes of glaucomatous participants with asymmetric vision loss (n=15, within person study), accounting for any non-visual differences between eyes/individuals. In Study 3 [Asfaw et al. 2020 PMID: 32555198], artificial scotomas were simulated in visually healthy people (n=55), to estimate how greatly natural eye-movements are affected by different severities of VF loss.

Results: Glaucoma patients could be discriminated from healthy peers with a sensitivity of 79% (95% confidence interval: 58–86%) at 90% fixed specificity (Study 1). Several eye-movement parameters differed on average between the better/worse eye of glaucoma patients and correlated with between eye differences in VF loss (Study 2). Eye-movements detected simulated cases of advanced VF loss, but effect sizes were notably small/noisy (Study 3).

Conclusion: Natural eye-movements differ as a function of glaucomatous VF loss (Study 2) and can be used to discriminate patients from healthy peers (Study 1). However, small effect sizes cast doubt on the clinical viability of current methods (Study 3). Implications and future/ongoing work using eye-movement sequences and artificial intelligence will be discussed. Data from our studies is freely available online (Asfaw et al. 2018 PMID: 29922707).

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Detecting and reconstructing visual field defects from free-viewing eye movements

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Perimetry, in the clinical setting is time consuming and difficult to perform, for patients and staff alike. There is a need for more intuitive perimetric screening methods, ideally being easier to administer so that they may even be used outside of a clinical setting and with challenging patient groups. Here, we present a method aimed at visual field defect recognition and localization, based on free viewing.

Participants were presented a diverse set of short movie clips monocularly with their gaze being tracked. For each participant, the basic gaze properties as well as the viewing priority was computed. Finally, based on the relative fixation frequency and the viewing priority across the visual field, it was attempted to locate the site of visual field defects.

Glaucoma patients were found to show a significantly lower viewing priority than their age-matched controls, moderated by the type of movie clip shown. Further, they demonstrated direction dependent deviations in saccade amplitudes. Using a kernel Principal Component

Analysis, it was possible to differentiate the patients with visual field defects from controls.

In contrast, the location of the defects on the visual field could not yet be identified, probably due to compensatory eye movements of the glaucoma patients.

Currently, we are working on an extension to the method, focusing on the relative location of saccade end-positions of the patients. From their temporal and spatial conformity to the controls we hope to derive a better understanding of how to predict the visual field defect location.

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Towards clinical application of eye movement perimetry

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Glaucoma is a progressive disease (of the eye) that irreversibly damages the retina and is the leading cause of blindness. Early glaucomatous damage affects basic visual functions such as stereo vision, motion perception, and the pupillary reflex. Accordingly, patients with (early) glaucoma experience difficulties estimating distances and experience timing problems when performing simple sensorimotor tasks that, e.g., require eye-hand coordination (playing tennis) and suffer from decreased contrast sensitivity resulting in difficulties with light-dark adaptation. Unfortunately, the current functional approach, standard automated perimetry, is unable to assess the above listed visual deficits. Thus, clinicians are hampered in obtaining reliable measurements for glaucoma diagnosis and management. In our lab, we employ eye movement perimetry, a functional visual test that is capable of assessing the (temporal) dynamics of visual perception by quantifying goal-directed eye movements and the pupillary reflex. Our approach allows us to characterize functional damage caused by glaucoma in both early and advanced stages. Crucially, we quantify pupil properties, e.g., pupil diameter and dilation/constriction time constants, and eye movements, e.g., direction and reaction times to visual stimuli in both monocular and binocular viewing conditions. This allows us to not only characterize classical monocular visual-field responsiveness but also to assess a patient's stereo vision and their (binocular) motion perception. Understanding of both monocular and binocular deficits in glaucoma, will aid the development of individualized therapy approaches that can be implemented at visual rehabilitation centers.

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Symposium 12. What do inter-item biases in perception and visual working memory tell about vision?

Memory reports are biased - for better not worse

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Memories, even those maintained over very short delays, are imperfect. Once committed to memory, information degrades or becomes warped. On its face, this seems problematic – after all, shouldn't our memories be a true snapshot of the past? Here we propose that instead of problematic, biasing information in memory can help stabilize mnemonic information to the benefit of future behavior. We will outline this perspective via several examples. First, we show that both visible and invisible forces exert an influence over the contents of short-term memory – biasing participants responses in a systematic manner, even when such contextual "forces" are irrelevant to the task. While integrating context in this manner does not appear to hurt performance, could it possibly even be adaptive? Second, we show a series of experiments demonstrating exactly this – the adaptive nature of biases that occur between multiple items maintained in short-term memory. In sum, we highlight several ways in which memory reports are warped by contextual information, and provide a framework in which to think of such biases as beneficial to behavior.

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Not all biases are created equal: Differences and similarities for between- and within-trial biases

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It is widely recognized that our perception and memories are not a direct and perfect representation of the physical world and what we remember about it. Different sources of information shape and bias how we perceive and remember visual objects. There has been recent and great interest in biases caused by items presented close in time (between trials) or simultaneously (within trial) and how these biases occur for perceptual and memory tasks. Such inter-item biases may lead to percepts and memories that are either attracted toward or repelled away from recently or simultaneously

presented visual information. It is still unclear if these biases come from a similar mechanism. In this talk, I will review recent findings in studies investigating the between (serial dependence) and within (working memory) trial biases and evaluate their differences and similarities in order to gain insight into their origin and mechanism.

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How precision in attended and ignored information influences sequential estimates

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Our visual environment is relatively stable from one moment to the next. Even if the current visual input is uncertain, it is generally likely to be similar to what we previously saw. Incorporating the information about prior and present stimuli is therefore advantageous when we construct our representations of the visual world. Indeed, recent input is often systematically biased towards previous input, a phenomenon coined serial dependence. Recently, a second bias was described where ignored visual input in a scene induces an additional bias that is repulsive in nature. The attractive bias pulls current input towards previous input while the repulsive bias pushes perception away from the ignored visual input.

According to Bayesian information integration accounts, previous and current input should be weighted by its reliability: Reliable past input should weigh more than unreliable current input and vice versa. However, it remains unclear whether human perception follows that strategy.

I will discuss evidence from a number of experiments showing that only the reliability of the current stimulus but not the previous ones drive the strength of sequential biases. Moreover, precision in the representation of its context also influences the magnitude of sequential biases.

I conclude that while a substantial amount of data shows that the magnitude of sequential biases is affected by the reliability of the current stimulus and its context, evidence for a Bayesian perspective of sequential biases is still lacking: Past and current input is not weighted in a Bayesian optimal manner.

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Demixing model of perceptual and memory biases

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Contextual biases are well-known in memory and perception. It is as if the human brain is simply incapable of estimating the features of one object without shifting the estimates towards or away from the other objects. The majority of the existing computational models link such biases to the properties of neural populations involved (the mechanistic level in Marr's classification), leaving open the question of their functional relevance (the computational level). In other words, why do biases exist? Are they somehow useful? I argue that these biases are inevitable when the brain tries to relate causes (i.e., objects) in the external world and the sensations they elicit. More specifically, the brain is presented with a mixture of sensory observations and has to demix them to determine the properties of the stimuli evoking them. This demixing model exhibits biased behaviour when stimuli are similar. Importantly, already in its simplest version, the model shows a repulsive-then-attractive bias pattern well-known in many perceptual illusions (e.g., the tilt illusion). With additional parameters, such as non-equal levels of sensory noise, the bias patterns change, allowing to explain why human observers show attractive biases in some conditions and repulsive in others. I argue that the biases then bear no functional role by themselves: they aren't there because they make perception more accurate or because they help to store information in memory. They are simply inevitable for any observer that tries to infer what is perceived.

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Is access in working memory crucial for serial dependence?

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Recently processed visual information can attractively bias information that is currently processed, a phenomenon known as serial dependence. Until now, it has been debated which phase of previous information processing is responsible for the attractive bias (the source) and which phase of the current processing is actually biased (the site). Previous research has suggested that the initial perception of a stimulus plays a crucial role for either the source or the site of serial dependence. In contrast, another line of evidence favored later processing stages including the maintenance of the stimulus in working memory or a related decision. Our research showed that when two items had to be encoded and memorized, but only one of them was selectively accessed for report, only the selected item consistently attracted the item that was reported in the subsequent trial. We also found that this attractive bias occurred regardless of whether an actual report followed the selective access in the previous trial. Examining neuronal data recorded with high temporal resolution, we observed an attractive shift of the reconstructed item representation only during its selective access and prior to the actual report. Taken together, our data suggest

that an active access to information in working memory is crucial for serial dependence, both for past information to exert an influence on current information and for the current information to become attracted to the recent past.

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Serial dependence and visual working memory: the hypothesis of an interference between low-dimensional representations

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Over the past decade, there has been growing interest in the phenomenon of serial dependence, the dependence of perceptual decisions on the recent past. Understanding serial dependence has eluded researchers since the dawn of Psychophysics and, despite the new wave of findings, the core questions remain: What is the nature of serial dependence? How does it relate to perception, memory, and higher-level functions? What is its functional role? In this talk, I will review the results of several recent projects from our group, in an attempt to mark a few important points. First, I will focus on the relationship between serial dependence in perceptual decisions and visual working memory, considering the possibility of a shared representational substrate. Second, I will present cases in which negative (e.g., repulsive) and positive (e.g., attractive) forms of serial dependence coexist, under the computational perspective of a hierarchical memory system. Last, I will discuss serial dependence at the computational level and why the observed results often fail to meet the predictions of normative and optimal models of vision.

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Symposium 13. Individual differences in mental imagery and anomalous perception

A novel model on divergent perception in imagery extremes

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Each person's reality is shaped by their subjective perception of the world. Predictive processing theory asserts that we weigh previous knowledge and expectations (i.e., priors), and sensory input from the environment, to shape our experience of reality. Priors have different levels (low, mid, high), corresponding to knowledge and expectations about low-level patterns (e.g., Gestalt processing), mid-level interpretation (e.g., seeing a face in the clouds), and high-level beliefs (e.g., "What I'm seeing is real"), respectively. Individuals rely to different extents on priors and sensory input, leading to differences in one's construction of reality. I aim to predict and explain these differences in conscious experience using a novel model rooted in predictive processing theory, called SP2. I theorize that two dimensions contribute to divergent perception: individual Sensory Precision and individual Strength of Priors (i.e., SP x SP, SP2). I hypothesize that overweighting or underweighting priors and sensory input is linked to different combinations of symptoms related to schizophrenia, synaesthesia, and mental imagery "extremes": aphantasia (blind mind's eye), and hyperphantasia (extremely vivid mind's eye). Previous research overwhelmingly suggests that vivid visual imagery is required to exhibit characteristics of synaesthesia and schizophrenia; however, recent findings demonstrate that individuals with aphantasia can experience both synaesthesia and anomalous perception. SP2 can be used to explain these seemingly paradoxical findings, and can predict patterns of divergent perception in future studies. Using this model, I will demonstrate that it is possible to determine the boundary between normal and abnormal divergent experience, and predict the likelihood of future pathology.

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The role of mental imagery in anomalous sensation and perception: Insights from Aphantasia

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Visual imagery is the ability to build a picture-like representation in the mind. For example, when asked to imagine a sunset, most people can create an image of the scene within their mind's eye. The vividness of visual imagery varies from person-to-person. For some, it is exceptionally strong and nearly as vivid as real-life perception, whereas for others it is virtually or completely absent, a condition known as aphantasia. But as well as differing in the vividness of imaged sensory information, people also differ in their sensory experience of the outside world. For example, some people experience sensory sensitivities (i.e., under- or over-responsiveness to bright lights, loud noises etc.; a trait often associated with autism), whereas others feel sensorily detached from the outside world (a type of 'anomalous perception' e.g., flattening of sensation). Yet another group of individuals with sensory differences – those

with synaesthesia – experience a merging of senses (e.g., perceiving colours in response to sounds). Presenting findings from the Sussex Imagery Lab, this talk will demonstrate how our internal sensory worlds (visual imagery) are linked to our external sensory perception of the outside world. Compared to people with visual imagery, we will show that aphantasics tend to report lower levels of sensory sensitivity, higher levels of autistic traits, more anomalous perception, and have an unusual profile of (certain types of) synaesthesia. These findings will be discussed in relation to the broader literature on imagery and sensory differences, showing how atypical internal worlds can mirror atypical external worlds.

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Phenomenological control: trait differences in generating expected experience

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Phenomenological control is the stable trait ability to meet expectancies and goals by generating experience. Trait phenomenological control is measured by scales of imaginative suggestions: verbal instructions which establish expectancies for anomalous experiences, (e.g., for auditory, gustatory, visual or olfactory sensations, delusions or apparently involuntary movement). This talk will present the results of large-sample studies showing relationships between measures of experimentally induced anomalous experience and imaginative suggestion scale scores comparable to those of the scale scores and the individual imaginative suggestions of which they are comprised. The measures reflect a wide variety of experience: head 'tingles' (ASMR), sound (Visually Evoked Auditory Response; vEAR), ownership of a fake hand (rubber hand illusion), pain (vicarious pain) and touch (mirror touch synaesthesia). A simple explanation for these relationships is that these effects are top-down phenomenological control effects in response to expectancies arising from experimental demand characteristics. Such relationships are not seen for all effects; we show recent evidence for no relationship between trait phenomenological control and response to a simple visual illusion (The Müller-Lyer Illusion). Consideration of trait phenomenological control is therefore informative when contemplating proposed mechanisms underlying reports of anomalous experience. The theory that phenomenological control centrally involves intentional mental or physical acts which are experienced as unintentional will be discussed, and evidence for and against relationships between trait phenomenological control and trait differences in visual imagery interpreted from this theoretical perspective.

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Perceptual Gains and Losses in Synesthesia and Schizophrenia

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Individual differences in perception are widespread. Considering inter-individual variability, synesthetes experience stable additional sensations, e.g., letters evoke a colour, while schizophrenia patients suffer perceptual deficits in, e.g., perceptual organization (alongside hallucinations and delusions). Is there a unifying principle explaining inter-individual variability in perception? There is good reason to believe perceptual experience results from inferential processes whereby sensory evidence is weighted by prior knowledge about the world. Perceptual variability may result from different precision weighting of sensory evidence and prior knowledge. We tested this hypothesis (Van Leeuwen et al., Schizophrenia Bulletin, 2021) by comparing visibility thresholds in a perceptual hysteresis task across medicated schizophrenia patients, synesthetes, and controls. Participants rated the subjective visibility of stimuli embedded in noise while we parametrically manipulated the availability of sensory evidence. Additionally, precise long term priors in synesthetes were leveraged by presenting either synesthesia-inducing or neutral stimuli. Schizophrenia patients showed increased visibility thresholds, consistent with overreliance on sensory evidence. In contrast, synesthetes exhibited lowered thresholds exclusively for synesthesia-inducing stimuli suggesting high-precision long-term priors. Additionally, in both synesthetes and schizophrenia patients explicit, short-term priors - as introduced during the hysteresis experiment - lowered thresholds but did not normalize perception. We interpret and discuss these findings with regard to the different levels of priors (low, mid, high-level) and in connection to the larger literature on sensory sensitivity and imagery in synesthetes and schizophrenia patients. Our results imply that perceptual variability might result from differences in the precision afforded to prior beliefs and sensory evidence, respectively.

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Symposium 14. Inhibition of Return and Visual Search

Inhibitions of return: Two inhibitory aftereffects of orienting

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Since it was discovered almost 40 yeas ago, the phenomenon of inhibition of return (IOR) has garnered intense interest and generated exciting findings and proposals. Among the most exciting proposals are Posner's suggestions that IOR is a novelty seeking mechanism that might function to increase the efficiency of visual search. Yet a 2015 survey of IOR experts revealed little agreement about its nature. We think these disagreements are rooted, at least in part, in IOR's dual natures: In the typical sequence of processing one form of IOR operates on early/input stages while the other form operates on later/output stages. We will present evidence using several diagnostics (central versus peripheral targets, joint consideration of speed and accuracy, and the locus of slack logic embedded in the psychological refractory period effect) to illustrate this dissociation and show the input form of iOR is generated when the reflexive oculomotor system is suppressed while the output form is generated when this system is not suppressed. We believe that despite these differences, both forms of IOR can serve the novelty seeking function and search facilitating function proposed by Posner & colleagues: the input form operates on a salience map that influences what we will attend to and the output form operates on a priority map that influences what behaviors (including orienting) we are likely to engage in.

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Inhibition of return in the oculomotor decision Process: Dissociating visual target discrimination from saccade readiness delays

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Saccades toward previously cued or fixated locations typically have longer latencies than those toward novel locations, a phenomenon known as inhibition of return (IOR). Despite extensive debate on its potential function, it remains unclear what the role of IOR in the oculomotor decision process is. Here, we ask whether the effect on eye movement planning is best characterized as a delay in visual target discrimination or as a reduction in readiness to execute the movement (saccade readiness). To evaluate this question, we use target-distractor tasks with clear speed-accuracy trade-offs. Simultaneously cueing both the target and distractor (or neither) we find longer latencies at the cued locations. Despite this delay in latencies, accuracy improves in line with the speed– accuracy trade-off curve (Experiment 1). This suggests that while visual target discrimination can progress unimpeded, saccade readiness is reduced. Based on this reduction in readiness we predict that the more saccades rely on visual target discrimination, the less their destination will be affected by inducing IOR. Indeed, after cueing either the target or an onset distractor (Experiment 2), short-latency, stimulus-driven, saccades are strongly biased away from the cued location, while the destinations of longer latency goal-driven saccades are affected only minimally. The fact that primarily stimulus-driven saccades are affected by inducing IOR is interesting as it can explain why the spatial bias associated with IOR is not consistently found.

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The effect of item relevance in visual search on saccadic Inhibition of return

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We investigated whether and to what extent saccadic Inhibition of return (IOR) is modulated by item relevance in repeated visual search. In Experiments 1 and 2, we showed that IOR was present during and after a search when no further search followed. In Experiments 3-5, we investigated whether IOR was modulated by the (prospective) item relevance. Participants searched a display consisting of pink and blue letters consecutively twice, knowing in advance the target color of Search 2 but not of Search 1. IOR during Search 1 was observed across all experiments such that saccadic latencies were longer to recently inspected than to non-inspected items. However, the effect of prospective relevance on IOR was less clear and will be discussed across the experimental manipulations.

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Top down goals influence Inhibition of return and return fixations

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Inhibition of return is claimed to be a foraging facilitator in complex visual behavior. IOR has been observed in various tasks including visual search, foraging and memorization and these tasks also show a reduced rate of return fixations as compared to those continuing in a forward vector. But, that these return fixations are more frequent than fixations at oblique angles introduces a puzzle. If IOR reduces return fixations, then reduced as compared to what? We look at rate of return fixations in two data sets where a) IOR is not observed in some of the instructed tasks and b) where salience is consistent across stimuli in a 'find the alien' space invaders game. In the first experiments, we observe a significant increase in return fixations in tasks where IOR to secondary probes is not observed. In the space invaders game we observe a different pattern of return fixations when the salience of stimuli is not a factor.

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Talk session 19. Lightness, brightness

A unified model of lightness computation, filling-in, and Troxler fading based on fixational eye movements

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At ECVP 2021, I presented a model of lightness computation that predicted lightness matches in the Staircase Gelb and related paradigms to within 5% error. The model was based on the assumption that edge contrasts are encoded in early visual processing by ON-center and OFF-center neurons having different characteristic neural gains, as estimated from neurophysiological data from macaque LGN. ON and OFF edge responses were integrated across space at the cortical level with an exponential falloff to produce ON and OFF network responses, which were in turn summed to compute lightness (perceived grayscale). Here, I take this model into the time domain. ON and OFF edge responses are now generated by fixational eye movements, modeled as a 2D random walk. Temporal differences in the activations of ON-center and OFF-center cells before and after each eye movement are computed as a means to compute spatially directed steps in log luminance at edges. As in the earlier model, ON and OFF edge responses are separately spatially integrated at the cortical level to produce ON and OFF network responses, and the sum of these defines lightness. The spatial lightness map is time-integrated to compute perceived lightness across multiple eye movements (the conscious percept and model output). This dynamic model of lightness computation captures all of the earlier data on lightness matching in Staircase Gelb and related experiments (including quantitative data on dynamic range compression in lightness), as well as additional data on lightness filling-in, the Chevreul illusion, and perceptual fading of stabilized images.

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How bright is your light?

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The candela is a pillar of vision science and part of the SI metric system, based on nearly 100 years old measurements of the luminosity function V(lambda), using mainly flicker photometry. We explored how well luminance, or alternative metrics could predict the perceived intensity of heterochromatic illuminations.

We placed two seven-channel LEDs on the sides of a neutrally painted room. Participants sat at its center, adapted to a D65 illuminant (58 cd/m2 at the wall). The illuminants were changed for 2 s during each trial, 31 participants were asked to choose the brighter side. We compared seven different measures of light intensity, including luminance, radiance, and a weighted sum of cones (wsLMS) derived from earlier experiments on the brightness of objects. For each pair of measures, we created conflicting pairs of illuminants and evaluated which predictor best agrees with human judgments.

Several of the predictors were accurate within the range of the observer consistency. Amazingly, both radiance and wsLMS were slightly better than luminance across all 630 trials. For the conflicting pairs, wsLMS was chosen over luminance in 62% of all trials. Only 4 of 31 observers had a preference for luminance over other predictors. The large majority instead preferred the wsLMS cone weights with equal L- and M-cone contributions and a small but significant contribution of S-cones. ipRGC excitation did not play a major role for any of the observers.

To conclude, some small adjustments to the candela might provide benefits to our ever more colorful lighting environment.

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Logic lost: lightness perception ignores Illumination cues across cast edges.

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Illumination information is almost universally thought to be highly important for the visual system in order to achieve lightness constancy. Helmholtz tied lightness perception to the calculation of illumination and dozens of more recent models (intrinsic image models, layer theories, edge classification/integration models, reverse optics models) have been built upon this assumption. Here we present strong evidence that the system ignores illumination information and constancy fails, despite abundant cues present at the illumination borders.

In a series of experiments, we projected a spotlight on a piece of paper that consisted of a black and a white background that each contained a smaller gray square. The spotlight totally enclosed the square on the black background. The illumination edge was either sharp or fuzzy and it was clear that the target was under a special illumination. Observers matched the lightness of the target and the backgrounds both within and outside the special illumination.

Our data showed a surprisingly large failure of constancy. The target always appeared much lighter than its actual reflectance value. This large error was not mitigated by the type of edge and it manifested even for the surfaces that were cut across by the illumination border.

We take these results to suggest that lightness theories should allow for larger errors than we previously had thought, even in cases in which illumination cues are clear, as is the case with cast edges.

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Evidence for the role of primary visual cortex in context-dependent brightness perception

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Perceived brightness of a surface does not only depend on its luminance but also on the context it is embedded in. Neuronal correlates, and which brain areas are involved in the processing of context-dependent brightness are questions still under debate. Here we use functional magnetic resonance imaging (fMRI) to investigate whether neural responses in primary visual cortex (V1) correspond to context-dependent brightness. To do so we use the simultaneous brightness induction (SBI), in which a central disk embedded in a darker surround appears to be lighter compared to when it is embedded in a lighter surround. In the fMRI experiment, we present participants with an achromatic disk embedded in an achromatic surround while they perform a demanding fixation task. We temporally modulate luminance of either the surround (induction condition) or the disk (real flicker condition). Unlike in previous studies in literature, here we systematically vary the flicker rate (1, 2, 4 and 8 Hz). Behaviorally, modulation of the surround at low frequencies produced the typical SBI. But the disk was perceived to have a constant brightness at higher surround frequencies. After controlling for possible long-range responses to the surround modulation, and comparing the induction with real flicker, we found that the pattern of V1 BOLD responses at different frequencies reflect the behavioral results. We interpret our findings as evidence for the role of early visual cortex in brightness perception.

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Numerosity tuning in human association cortices and local image contrast representations in early visual cortex

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Humans and many animals perceive visual numerosity (object number) and neurons showing numerosity-tuned responses have been found in several species. However, it remains unclear how the brain estimates numerosity from visual images while disregarding object size and spacing. Recent results show that human early visual cortex responses monotonically increase following numerosity, regardless of object size or spacing. This is surprising because numerosity is typically considered a high-level visual or cognitive feature while early visual responses are normally thought to follow image contrast in the spatial frequency domain. We therefore asked whether these early visual responses could be explained by the spatial frequency content of numerosity displays. We found that aggregate Fourier power (contrast at all orientations and spatial frequencies) followed numerosity closely but nonlinearly, with little effect of object size, spacing or shape. This would allow straightforward numerosity estimation from spatial frequency domain image representations. Using 7 Tesla fMRI, we showed monotonic responses originate in primary visual cortex (V1) at the stimulus's retinotopic location. Responses here and in neural network models followed aggregate Fourier power more closely than numerosity. Truly numerosity tuned responses emerged after lateral occipital cortex and were independent of retinotopic location. We propose numerosity's straightforward perception and evolutionarily preserved neural responses may result from the pervasive spatial frequency analyses in early visual processing throughout the animal kingdom.

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Binocular response to light: contrast matching of luminance flicker

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Early work on binocular combination of luminance found near-linear binocular combination for increments against a dark background. However, for luminance decrements, and for spatial contrast (i.e. gratings), more severe nonlinearities are apparent. Typical experiments involve matching perception of a binocular or monocular standard, using targets with different relative luminances or contrasts in the two eyes. Such experiments have not been attempted using temporal contrast (flicker) stimuli, which we have used in recent pupillometric and steady-state EEG investigations into binocular combination.

Here, we measured the ability of participants to match disks of flickering light in a two-interval matching procedure. Participants were presented with a standard disk that flickered at a set contrast level (either 24% or 48%) in one interval, and a target disk flickering at varying contrast levels in a separate interval (randomly ordered). The ratio of flicker amplitudes in the left and right eyes was varied across blocks (0, 0.25, 0.5, 0.75, 1), and participants judged which interval they perceived as having the more intense flicker. Stimuli were viewed through a mirror stereoscope, and all disks flickered at a frequency of 2 Hz.

The results show a near-linear binocular summation for luminance flicker, consistent with our recent EEG results, but very different from previous findings for spatial contrast modulation. We account for all three data recent sets (matching results, EEG data and pupillometry data) in a single modelling framework where the weight of interocular suppression determines the signal combination properties at high contrast.

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Talk session 20. Computational Modelling

Predictive coding is a consequence of energy efficiency in neural networks

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Predictive coding represents a promising framework for understanding brain function, postulating that the brain continuously inhibits predictable sensory input, ensuring a preferential processing of surprising elements. A central aspect of this view on cortical computation is its hierarchical connectivity, involving recurrent message passing between excitatory bottom-up signals and inhibitory top-down feedback. Here we use computational modelling to demonstrate that such architectural hard-wiring is not necessary. Rather, predictive coding is shown to emerge as a consequence of energy efficiency, a fundamental requirement of neural processing. When training recurrent neural networks to minimise their energy consumption while operating in predictive environments, the networks self-organise into prediction and error units with appropriate inhibitory and excitatory interconnections and learn to inhibit predictable sensory input. We demonstrate that prediction and error units can reliably be identified through biases in their preactivation, pointing towards fundamental properties of these units in the predictive coding framework. Moving beyond the view of purely top-down driven predictions, we demonstrate via virtual lesioning experiments that networks perform predictions on two timescales: fast lateral predictions among sensory units and slower prediction cycles that integrate evidence over time. Our results, which replicate across two separate data sets, suggest that predictive coding can be interpreted as a natural consequence of energy efficiency. More generally, they raise the question of which other computational principles of brain function can be understood as a result of physical constraints posed by the brain, opening up a new area of bio-inspired, machine learning-powered neuroscience research.

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A critical test of deep convolutional neural networks' ability to capture recurrent processing using visual masking

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Recurrent processing is a crucial feature in human visual processing supporting perceptual grouping, figure-ground segmentation, and recognition under challenging conditions. Most researchers agree on a need to incorporate recurrent processing in deep convolutional neural networks, but the computations underlying recurrent processing remain unclear. In this paper, we tested the ability of a class of deep convolutional neural networks, deep residual networks (ResNet), to capture recurrent processing.

ResNets' computations have been shown to be equivalent to unrolled time steps of recurrent neural networks. We used ResNets of varying depths to model varying levels of recurrent processing in electroencephalography recordings. A total of 62 human subjects and 50 ResNets completed an object recognition task. Humans completed the task under visually unmasked and masked conditions, to manipulate the degree of recurrent processing. We replicated effects from an earlier study showing that deeper networks performed similarly to humans under unmasked conditions; whereas, shallower networks performed similar to humans in masked conditions. We also show that deeper ResNets capture more recurrent signals than shallower ResNets in unmasked trials; though the differences between deep and shallow models decreased for masked trials, when recurrent processing was disrupted. By contrasting the explained variance of ResNets in unmasked and masked trials, we show that recurrent signals set in as early as ~98ms and gradually increase across time until a peak at ~200ms. Thus, we conclude that the excitatory additive recurrent processing, provided by ResNets and recurrent neural networks capture a portion of recurrent processes in humans.

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Muscular reflex gains reflect evidence accumulation and changes of mind in decision making

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The brain's decision processes are based on a continuous flow of information deep into the motor system, and are even expressed in the reflex gains of muscles. Continuous flow also implies that the information stream remains sampled during an ongoing response, which could lead to a revision of the decision, called a change of mind (CoM). Here we ask whether the brain's preparatory state during decision formation, as indexed by the reflex gain, differs between CoM and non-CoM trials. Participants (n=16) had to infer the motion direction in a random dot motion stimulus and indicated their choice by a goal-directed reaching movement. Using EMG, we quantified the reflex gain of the involved muscle in response to a brief stretch at the end of the visual stimulus. We tested the hypothesis that reflex gains preceding CoM trials are smaller. As a validation of our paradigm, participants showed a significant number of CoM trials, which improved performance. A Drift Diffusion model (DDM) could well describe the participants' non-CoM and CoM behaviour. Reflex gains scaled with the amount of information in the stimulus, and show differences (despite similar decision variables in the DMM) in CoM and non-CoM trials. We conclude that the strength of the ongoing coupling between visual sampling and peripheral motor control determines changes of mind in decision making.

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A multi-task learning approach based on convolutional neural networks for image aesthetic evaluation

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The success of deep learning has been increasing rapidly over the last decade. Deep neural networks have achieved impressive results in many areas. When it comes to image data, convolutional neural networks (CNNs) have demonstrated outstanding performances in a variety of tasks. The performance of CNN-based models has yielded major advances from computer vision to game playing. Today, CNNs are also an essential part of computational aesthetics. In this study, we propose a deep CNN with multiple outputs to learn the aesthetic attributes alongside the overall score during training. The aim is to obtain better feature representations via multi-task learning, and consequently provide a better understanding of the aesthetic preferences. The proposed architecture is based on transfer learning which uses a pretrained network to extract feature representations on the ImageNet database. We conduct experiments on Aesthetics and Attributes Database (AADB) to observe the impact of the proposed model as well as interpreting the feature maps visually. Based on the multi-task learning approach for predicting the aesthetic scores of images, the correlation between the aesthetic score and attributes gives information about which attributes contribute the most to the aesthetic score of the image. Moreover, experimental results on the AADB database provide insight into the different roles of low-, mid- and high level features in determining aesthetic preferences for images.

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Spike-timing dependent plasticity among multiple layers of motion-sensitive neurons: a feedforward mechanism for motion extrapolation

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The ability of the brain to represent the external world in real-time is impacted by the fact that neural processing

takes time. Because neural delays accumulate as information progresses through the visual system, representations encoded at each hierarchical level are based upon input that is progressively outdated with respect to the external world. This is particularly relevant to the task of localizing a moving object – because the object's location changes with time, neural representations of its location potentially lag behind its true location. It has therefore been proposed that the visual system utilizes the predictive nature of motion to extrapolate moving objects along their trajectory. Burkitt and Hogendoorn (2021, https://doi.org/10.1523/JNEUROSCI.2017-20.2021) showed how spike-timing dependent plasticity (STDP) can achieve motion extrapolation in a two-layer, feedforward network of velocity-tuned neurons, by shifting the receptive-fields of second-layer neurons in the opposite direction to a moving stimulus.

The current study extends this work by implementing two important changes to the network to bring it more into line with biology: we expanded the network to multiple layers to reflect the depth of the visual hierarchy, and we implemented more realistic synaptic time-courses. We examine the degree to which STDP can facilitate compensation of neural delays across six layers, and show that the multi-layer network achieves cumulative compensation comparable in magnitude to the delays incurred in visual processing. We also explore the effect of additional delays imposed on the network by the integration time of the membrane potential.

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A topographic network showing tuned responses to visual short-term memory load.

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Representing image content in visual short-term memory is essential to performing many visual tasks. But how does the brain respond to the load on visual short-term memory? We measured responses to varying numbers of items in visual short-term memory using 7T fMRI. Our displays had a constant numerosity but required remembering a variable number of items. We analyzed the responses with neural population response models tuned to the remembered number (i.e. visual short-term memory load). We found eleven bilateral areas showing tuned responses to visual short-term memory load in the dorsal stream and fronto-parietal attention network. This tuning was better captured by logarithmic Gaussian functions of remembered item number than by linear Gaussian or monotonic functions. These responses were invariant to task difficulty and trial order. We found gradual changes in the preferred visual short-term memory load of these neural populations across the cortical surface within these areas, such that they formed topographic maps. Superior parietal maps were the largest, showed the clearest responses and responded to the broadest range of short-term memory loads (i.e. had broader tuning widths). Left hemisphere maps showed clearer responses, but all maps were similarly sized in both hemispheres. We found hierarchical transformations of visual short term memory load representations from posterior to anterior maps, focusing increasingly on higher visual short-term memory loads. These representations of visual short-term memory load mirror properties of other quantity representations and sensory cortices and demonstrate that tuned neural responses can encode task properties as well as stimulus properties.

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Talk session 21. Object Perception II

When visuals and meaning collide: The effects of visuo-semantic clashes on object discrimination

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How do we tell things apart, and what happens if things do not look like they should? We used deep layer activations of a convolutional neural network to extract the main two dimensions ("animate-looking/inanimate-looking" and "stubby/spiky") on which objects visually differ. We projected new object images onto this two-dimensional object space, obtaining information about their visual properties, and used them in a foraging task where participants had to tell the objects apart. In study 1 (N=73) and as expected, greater object space distance between target and distractor images generally resulted in faster foraging as the objects were more visually dissimilar. Unexpectedly, this was only true when the objects' visual properties were congruent with their meaning. When an object's appearance was in contrast with its identity (inanimate objects that looked animate, as estimated by network activations), visual properties were downweighed or even negatively weighed. To firmly establish this effect, we ran a preregistered study 2 (https://osf.io/g7kuy) with new images where participants foraged for objects where their appearance was either congruent or incongruent

with their meaning (animals and inanimate objects that either did or did not look animate). Participants (N=43) first foraged for objects and then rated their semantic relatedness. When visual qualities were congruent with the objects' meaning, visual similarity affected foraging speed while semantic relatedness had basically no effect. When visual and semantic qualities clashed, visual similarity had minimal effect while the role of semantic target-distractor relatedness increased. We suggest that the brain ignores visual information when it is misinformation.

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A sense of style; comparing style perception between local and global

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If two painters paint the same scene, the appearance difference can be called style. The distinguishing features result from artists' use of color, shading, brushstroke etc. We are interested in how people perceive different depiction styles, when they are either presented with a detail or the whole paintings.

In a previous study, we chose fragments from 42 oil paintings as stimuli. All fragments were depictions of apples. The creation years of the original paintings varied from 15th to 21st century, and their location of production varied from southern Spain to the northern Netherlands. We gathered similarity judgement data using triplet method and reached a 3D perceptual space. In the current study, we used the same 42 paintings as stimuli, with whole paintings instead of fragments, and gathered similarity judgement data from 20 online participants. This time the ordinal embedding analysis also led to a 3D space.

We compared the two perceptual spaces, the first two dimensions in the new 3D space had high correlations with the fragment 3D space ($r = 0.66, 0.77$), suggesting people used similar attributes (e.g. brushstroke) to judge style similarity. While the third dimension was very different ($r = -0.06$), suggesting that different attributes were taken into consideration when using whole paintings instead of fragments. Another surprising finding is creation year always showed a high correlation with dimension 2 ($r = 0.77$ in the current study, $r = 0.75$ in the fragment study). In conclusion, we found a certain scale invariance in the perception of style.

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Serial dependence in brain representations of visual objects

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Current perception can depend on what has been seen in the recent past, a phenomenon known as serial dependence. We examined the brain correlates of serial dependence by asking participants to categorize ambiguous morphs into one of three categories: face, car or house, while recording EEG. We used representational similarity analysis (RSA) to examine whether information in the current brain response included aspects of the past. RSA is a multivariate technique that looks at whole-brain correlations between different conditions. As expected, the brain representation of a subset of faces was more like another subset of faces than it was like a subset of houses or cars. The brain representation of a subset of morphs was more like the representation of another subset of morphs when both were preceded by the same object, such as a car, relative to when the two subsets were preceded by two different objects, such as a car versus a face. These results indicate that the brain representation of a currently viewed object is influenced by stimulus history.

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Visual category representations in the infant brain

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Visual categorization is a human core cognitive capacity that depends on the development of visual category representations in the infant brain. However, the exact nature of infant visual category representations and their relationship to the corresponding adult form remains unknown. Our results clarify the nature of visual category representations from electroencephalography (EEG) data in 6- to 8--month-old infants and their developmental trajectory towards adult maturity in the key characteristics of temporal dynamics, representational format, and spectral properties. Temporal dynamics change from slowly emerging, developing representations in infants to quickly emerging, complex representations in adults. Despite those differences, infants and adults already partly share visual category representations. The format of infants' representations is visual features of low to intermediate complexity, whereas adults'

representations also encode high complexity features. Theta band neural oscillations form the basis of visual category representations in infants, and these representations are shifted to the alpha/beta band in adults. Together, we reveal the developmental neural basis of visual categorization in humans, show how information transmission channels change in development, and demonstrate the power of advanced multivariate analysis techniques in infant EEG research for theory building in developmental cognitive science.

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Rapid statistical learning of object part co-occurrence in humans and monkeys

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We quickly learn statistical regularities of our environment, but whether this confers any task advantage remains unknown. Here, we investigated this issue using parallel experiments in humans and monkeys.

We created two sets of spatially separated trigram objects. In set-1, 24 specific A-B pairs were combined with 24C parts to create 576 trigrams. Likewise, in set-2, 24A parts were combined with 24 specific B-C pairs. We therefore reasoned that repeated viewing of Set-1 or Set-2 should result in learning of specific part combinations (as they repeat 24 times more) over others.

In Experiment-1, 31 human participants viewed Set-1 or Set-2 objects in one-back task. When asked to choose between AB vs. BC, participants identified familiar pair with higher accuracy. Then they were tested on same-different task with trigram objects, in which either AB (e.g., A1B1C1 to A2B2C1) or BC (e.g., A1B1C1 to A1B2C2) pairs changed. Participants detected familiar pair change faster than unfamiliar pair change (average response time: 757 $\pm$ 7.6ms for familiar; 783 $\pm$ 8.2ms for unfamiliar, $p<0.01$, ranksum test, 12 pairs x 7 repetition/conditions).

In Experiment-2, two monkeys were familiarized during passive viewing to Set-1 or Set-2, and then were tested on the exact same-different task as human. Each monkey detected familiar pair breaking more accurately than unfamiliar pair breaking (average accuracy: 90% for familiar, 74% for unfamiliar, $p<0.05$, unpaired t-test across 12 pairs/conditions).

Taken together, our results show that both humans and monkeys show rapid learning of statistical regularities with clear but opposite impact on change detection.

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Temporal dynamics of shape-invariant real-world object size processing

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Real-world size is a behaviorally relevant object property that is automatically encoded, is reflected in the organization of the human ventral temporal cortex, and can be decoded from neural responses as early as 150 ms after stimulus onset. However, while real-world size is a distinct, conceptual object property, it strongly correlates with at least two other object properties: rectilinearity (large objects typically have more rectilinear features) and fixedness (large objects are more often fixed in the environment). Here, we aimed to dissociate the temporal profile of object size processing from that of covarying shape and fixedness properties. During EEG recording, participants (N=33) viewed isolated objects that were drawn from a 2 (real-world size: large, small) x 2 (shape: rectilinear, curvilinear) x 2 (fixedness: fixed, transportable) design. This design allowed us to decode each dimension (e.g., size) across the other dimensions (e.g., shape, fixedness). For example, we tested whether (and when) a classifier trained to distinguish large from small fixed and/or rectilinear objects (e.g., bed vs mailbox) successfully generalized to distinguish large from small transportable-curvilinear objects (e.g., airballoon vs balloon). Across posterior electrodes, cross-decoding of real-world size was significant from 350 ms after stimulus onset for all cross-decoding splits. Similar cross-decoding analyses of the other two object properties revealed cross-decoding of shape from 170 ms and no significant cross-decoding of fixedness at any time point. These results indicate that higher-level (shape-invariant) representations of real-world object size emerge relatively late during visual processing.

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Talk session 22. Visual Search & Foraging

Can natural scenes guide attention to more than one location? Evidence from eye movements in contextual cueing

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Contextual cueing studies have shown that people are faster to visually search for and discriminate a target when it is in a consistent position within a repeated configuration than when it appears in novel configurations. However, when a target is shown alternating between two or more different locations in a repeated context the search benefit is smaller, occurs later, and might result from an average of benefits for one location and costs for the other(s). In two experiments, we investigated whether in real-world scenes, subjects show a comparable contextual cueing effect for contexts with one or two possible target locations. Experiment 1 replicated a study by Brockmole and Henderson (2006) demonstrating a pronounced contextual cueing effect in real-world scenes. Subjects searched for a small "T" or "L" superimposed on photographs of real-world scenes. Half of the trials showed repeated scenes with one possible target location each, half showed novel scenes. In Experiment 2, two conditions were added. In one of them, targets appeared in repeated scenes alternating between two possible locations per scene. In the other condition, targets appeared in repeated scenes but at new locations constrained to one screen side. Besides shorter manual response times, shorter times and fewer fixations until first target fixation in repeated scenes demonstrated that contextual cueing does not only occur for one but also two cued locations and to some extent even for new locations, consistent with a localization of the contextual cueing effect in attentional guidance.

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Developing a collaborative framework for naturalistic visual search

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While much research has investigated the mechanisms of visual search behaviour in laboratory-based computer tasks, there has been relatively little work on whether these results generalise to more naturalistic search tasks and thus how well existing theories explain real-world search behaviour. In addition, work on real-world search has often been carried out by researchers working in very different disciplines, leading to a high degree of task fragmentation. We present preliminary work (N=33) detailing our development of a 'naturalistic search task battery', which aims to provide a suite of open source, reproducible and standardised real-world search tasks, thus enabling the generation of comparable data across multiple studies and aiding theory and modelling in this area. We show that we can replicate findings from previous real-world search tasks using Lego (Sauter et al, 2020), demonstrating set size effects and differences between different types of search conditions (colour, shape, and their conjunction). We also show target absent/present effects and effects of scene regularity using a 'bookcase' task where participants search for specific books on shelves. Finally, we use a 'jigsaw' task and a 'Lego building' task as examples of more complex real-world search tasks and show how we are able to use them to consider the effects of strategies and the use of templates. We also consider whether performance on one task is able to predict performance on another, and thus to what extent similar cognitive capabilities underlie diverse 'real-world' search tasks.

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Visual search efficiency strongly modulated by irrelevant surface level properties.

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We showed in our previous work that although average visual search strategies can appear stochastic, individual strategies range dramatically from optimal, through stochastic, to counter-optimal. These results were based on simple line segment stimuli which we assumed would minimize variation in search behaviour between individuals. In the follow up series of experiments, we changed simple surface level properties, irrelevant to the task, to observe whether individual differences would generalize across these properties. Our measure of search efficiency is defined as the proportion of fixations to locations providing new information about the target location. Across five experiments (with a total N of 105) we measured search efficiency of healthy observers as they searched through line segments, desktop icons, polygons and pens. The optimal strategy across all experiments was the same (fixation of regions that would provide maximum information gain) and equivalently easy to apply across contexts. Despite this, we observed large differences in search efficiency. Specifically, when participants were searching for a state (specific orientation) search strategy was highly variable and far from optimal. In contrast, searching for an identity induced more uniform and mostly optimal search strategies. Striking differences in search behaviour dependent on context suggests caution when generalizing results even from one simple lab task to another. These results can also help resolve some inconsistencies in the visual search literature in which the search context may have played a role.

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Spatiotemporal associations between neural representational similarity and visual task performance

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Capacity limitations in visual tasks can be observed when the number of task-related objects increases. An influential idea is that such capacity limitations are determined by competition at the neural level: two objects that are encoded by shared neural populations interfere more in behavior than two objects encoded by separate neural populations. However, the neural representational similarity of objects varies across brain regions and across time, raising the question of where and when competition determines task performance. Furthermore, it is unclear whether the association between neural representational similarity and task performance is common or unique across tasks. Here, we used fMRI, MEG, EEG and deep neural networks (DNN) to provide a detailed spatiotemporal association between neural representational similarity and performance on two tasks, both involving the same set of two-object displays. In the visual search task, participants located a pre-cued target object, while in the same/different task participants indicated whether the two objects were the same or different. Separate groups of participants viewed the individual objects in neuroimaging experiments to establish the neural representational similarity of the object set. For both tasks, the pairwise behavioral interference was correlated with neural representational similarity throughout the visual system, from 100 ms after onset, and in all layers of a DNN. Semi-partial correlation analysis, however, revealed task-specific associations, with the same/different task uniquely associated with early/posterior neural similarity, and the visual search task uniquely associated with late/anterior neural similarity. These results provide a detailed task-specific mapping between neural similarity and behavioral interference.

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Top-Down Suppression of Negative Features Applies Flexibly Contingent on Search Goals

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During visual search, bottom-up (e.g., physical salience) and top-down factors, including task relevance of a target-defining feature, drive attention. For example, target-defining features involuntarily capture attention depending on an attentional control setting that the observer sets up to search for the respective features, whereas irrelevant features are ignored. We recently showed that task-relevant negative features (e.g., red if a target is defined as not red) also guide attention, but through top-down suppression. Here, we investigated the flexibility of attentional guidance by to-be-suppressed features. Instructions varied from trial to trial and told participants to search for a target defined by a negative (e.g., a nonred horizontal bar; negative instruction) or a positive (e.g., a blue horizontal bar; positive instruction) feature. We used different peripheral singleton cues presented at the target position (valid condition) or away from the target (invalid condition) to examine if negative features were suppressed depending on instructions. In negative instruction trials, cues with the negative feature elicited slower search times in valid than invalid trials, indicating suppression. In contrast, negative color cues elicited no significant search time difference in positive instruction trials (i.e., no suppression).

Our results suggest that suppression is flexible, top-down, and a direct function of task instructions. Suppression is, thus, not restricted to an inflexible usage of the negative feature based on, for example, rote learning only.

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Ensemble perception, categorization, and visual search

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Ensemble perception is the ability to efficiently represent groups of similar objects by their summary statistics. Observers are better at perceiving the means of image sets than remembering presence of a particular set member. Observers automatically and implicitly extract averages of image sets, on-the-fly, on a trial-by-trial basis. Categorization is a fundamental sensory-motor ability facilitating rapid behavioral responses to complex situations. It recognizes similarities between objects, events, or ideas, and organizes associated abstract groups. High-level visual search tests categorization, requesting observers to find exemplars of named categories among heterogeneous objects. Paradoxically, category exemplars and ensemble images share sufficient features to allow recognizing them as category or set members, but each one is different, or we would have a useless tautology. We use the "individual differences" paradigm, asking if categorization, high-level visual search, and ensemble perception depend on the same or different underlying mechanisms. If separate mechanisms exist, then Nature's manipulations may lead some individuals to have particularly sensitive mechanisms for one, and other individuals for the other. Performance subserved by different mechanisms should predict each other less

than performance subserved by the same mechanism. We find correlated performance for different features and presentation procedures, for explicit but not implicit ensemble perception; correlations for face detection and basic-level ensemble perception, but uncorrelated performance for complex categorization and ensemble perception. Results have important implications for placing perceptual mechanisms at different visual hierarchy levels.

Support: Israel Science Foundation (ISF)

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Talk session 23. Peripheral Vision

Robust feature blanking effect for a wide range of spatial frequencies

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Across saccadic eye movements, objects occupy two successive locations on the retina, one before (presaccadic location) and one after (postsaccadic location) the movement. Changes in stimulus features often go unnoticed, but they become accessible when a short interruption is introduced to the stimulus presentation from saccade onset until 200 ms after saccade landing. This drastic improvement in discrimination performance is called the blanking effect. Recent evidence suggests that the blanking effect is abolished or diminished for small stimuli and stimuli without contrast of luminance, suggesting that transsacadic processes might heavily rely on the magnocellular system. To test this idea, we investigated whether the blanking effect is limited to low spatial frequencies. Participants executed a saccade to a high-contrast grating presented either to the left or right side of fixation at either six or ten degrees of eccentricity. The grating's spatial frequency varied randomly between 0.5, 1, 2, 4 and 8 cycles per degree of visual angle. During the saccade, the grating changed orientation either in the clockwise or counterclockwise direction either immediately or after a 200ms blanking period. Participants reported the direction of the orientation change. Blanking improved performance reliably at each eccentricity and for each spatial frequency with the largest effect for targets presented with 2 cycles/degree at 6 degrees. Our results demonstrate an impressive robustness of the feature blanking effect and suggest that the transsaccadic processes of low-level visual features possibly go beyond the magnocellular system.

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Decoding remapped stimulus information from EEG in the pre-saccadic period.

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Saccadic remapping is the updating of retinotopic coordinates across saccades. This process is thought to compensate for the shift of the visual world across the retina with eye movements. It is suggested that prior to a saccade, neurons currently representing a visual stimulus predictively shift this representation to neurons whose receptive fields will encompass the stimulus after a saccade. There is intense debate around whether this process involves only the updating of spatial pointers, or whether featural information, such as orientation, is also remapped. In this study, we recorded neural activity using electroencephalography (EEG) during a saccade task. Participants made saccades between two fixation points while covertly attending to oriented gratings briefly presented at various locations on the screen. Data recorded during trials in which participants maintained fixation were used as training data for multivariate pattern analyses. Subsequently data collected during saccade trials were used to test for the presence of stimulus information at the post-saccadic retinotopic location shortly before the saccade (i.e. the pre-saccadic period). These analyses allow us to reveal the contents and temporal dynamics of the remapped response. We found preliminary evidence that information about stimuli presented in the pre-saccadic period is encoded in the remapped position. Most noteworthy is the indication that stimulus orientation is predictively remapped, supporting the idea that stimulus features are represented at their post-saccadic retinotopic location in the pre-saccadic period. This finding advances our understanding of how the brain keeps track of objects in the external world despite constantly changing retinotopic input.

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Foveal feedback and the discrimination of peripheral objects: timing and role.

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In recent years, evidence has accumulated in favor of an involvement of the fovea-encoding portion of V1 in the processing of peripheral stimuli (Stewart, 2020). The neural substrate is thought to be a location invariant feedback from higher visual areas to the foveal cortex in V1 (Williams, 2008). In a series of behavioral experiments,

Fan et al. (2016) showed a deterioration of performance during peripheral object discrimination induced by a foveal distractor presented with a delay of 150-300ms. By replicating the paradigm with more SOAs (60 levels), our primary aim was to extend the previous result to better characterize the temporal dynamics of foveal feedback. Specifically, across three experiments, we show that 1) the disruptive effect of the foveal noise over the peripheral task is replicable even when data are collected online; 2) the dipper function produced by the noise approximates a quartic with a minimum between 100-150ms with no obvious secondary peaks; 3) the Foveal noise also causes a shift in criterion, which tends to be more conservative; 4) the timing and amplitude of the dip do not change significantly when comparing low- vs high-level visual stimuli. Overall, our results confirm previous findings and show that the foveal noise effect is robust to both low-level and high-level visual processing tasks. We also showed that this effect is earlier than previously found and temporally distinct from the response bias. We therefore suggest that foveal noise acts on two mechanisms, one more perceptual and earlier and one more cognitive and delayed.

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Optic flow processing in macular degeneration patients

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Macular degeneration (MD) is a visual pathology which involves a progressive loss of central vision. It is established that MD patients have important deficits for visual categorization tasks but much less is known about their ability to process dynamic visual scenes. Here, we characterized their perception of optic flow, the pattern of motion that falls on the retinas during locomotion. We performed psychophysical experiments in 12 MD patients (mean age: 64.67 ± 14.72, range: 26-80). Stimuli consisted of random-dot kinematograms (RDKs) projected on a large screen (56° x 40°). For each of the three components of optic flow (translational, radial and rotational), patients were involved in a 2-alternative forced choice task (2-AFC) and had to report their perceived motion direction (leftward versus rightward for translational, inward versus outward for radial and clockwise versus anti-clockwise for rotational patterns). We manipulated motion coherency (i.e. the percentage of dots moving in the same direction) and estimated the thresholds corresponding to 80% of correct discrimination. Thresholds were very low for radial and rotational patterns (22.67 ± 23.05% and 17.72 ± 8.22% on average) and comparable to those measured in an age-matched control group (20.10 ± 10.81% and 18.41 ± 9.75%). In contrast, thresholds for translational patterns were more variable and higher (62.03 ± 32.70%) than in the control group (38.39 ± 24.55%). Altogether, our results suggest that selectivity to radial and rotational optic flow patterns is preserved in MD patients, in line with previous findings on self-induced motion perception.

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Eyes up! Presaccadic attention enhances contrast sensitivity, but not at the upper vertical meridian

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Visual performance not only decreases from fovea to periphery but also has striking polar angle asymmetries: It is better along the horizontal than vertical meridian, and along the lower than upper vertical meridian. Both exogenous and endogenous attention uniformly improve performance, preserving these asymmetries. We investigated how presaccadic attention—deployed automatically to the upcoming fixation during saccade preparation—modulates perception around the visual field. Does presaccadic attention benefit performance more where it is worse and diminish polar angle asymmetries?

Observers performed saccades to centrally cued targets at the four cardinals (~8.5° eccentricity) and discriminated the orientation of a grating presented just before saccade onset. We manipulated grating contrast to measure contrast sensitivity and fit contrast response functions to assess contrast- and response-gain.

We (1) replicate performance asymmetries during fixation—higher contrast sensitivity along the horizontal than vertical meridian and the lower than upper vertical meridian; (2) document the same polar asymmetries during saccade preparation; and (3) show that presaccadic attention interacts with location: It enhances contrast sensitivity and results in response-gain at the horizontal and lower vertical meridian but not at the upper vertical meridian. (4) This surprising absence of a performance advantage preceding upwards saccades is not explained by differences in saccade latency or precision and documents a rigid perceptual limitation along the upper vertical meridian, likely due to anatomical constraints. Our findings question the generalizability of presaccadic attention measurements collapsed across polar angle and call for a systematic study of eye movements around the visual field.

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Right fronto-parietal tACS at beta frequency reduces the influence of visual crowding during letter identification

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Visual crowding refers to the impairment of visual objects perception induced by the presence of neighboring flankers. Visual objects perception depends on the integration of low and high-level representations regulated by the communication between the dorsal and the ventral visual pathways in the brain. Neural oscillations within the beta-band (15-25 Hz) in fronto-parietal and parieto-occipital sensors showed to be crucial for such communication to occur. Crowding also hinders letter identification, inducing a reduction of beta-band power. Here, we aimed at reducing the effect of visual crowding during letter identification, using bi-focal high-definition transcranial alternating current stimulation (tACS) in the beta-band applied on different cortical sites. Participants (N=24) were asked to report the orientation of a peripheral target letter positioned nearby two flankers, while target-flankers distance was manipulated. In 3 separate sessions, we administered beta-band tACS with a right fronto-parietal montage, a bilateral parietal montage, and a sham (placebo) protocol. EEG was recorded before, during, and after the task. Higher accuracy in letter identification was found only for the left hemifield when the stimulation was applied in the fronto-parietal right electrode sites with respect to sham. Preliminary EEG data showed that this protocol successfully modulated power in the beta band over the stimulated sites. Differently, no crowding modulation was found using the bilateral-parietal protocol. Results corroborate previous findings about the importance of the beta-band activity across right fronto-parietal sites for the impact of visual crowding during letter identification, paving the way for possible rehabilitation protocols for vision-related reading impairments.

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Talk session 24. Perceptual Awareness & Consciousness

Decoding visual predictions from occipital alpha oscillations

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It takes time for the brain to process incoming sensory information. This means that there is a lag between when an event happens in the outside world and when it is registered in the brain. Growing evidence suggests that the visual system employs predictive mechanisms to help overcome this lag and better align neural representations with the outside world. Here, we investigated whether signatures of predictive processing are evident in EEG time-frequency spectra. Across two experiments, participants viewed an apparent-motion stimulus moving along a circular path, while EEG was recorded. To investigate the encoding of predictive information, we first developed a method of deriving spatial probability maps from oscillatory phase information, using circular statistics. With this method, we demonstrate that it is possible to decode the on-screen location of a stimulus from the phase angle of alpha oscillations (8-12 Hz) over the occipital cortex. Crucially, we show that 'representational overshoot' occurs following the unexpected disappearance or reversal of a stimulus, suggesting that the underlying neural mechanisms are indeed predictive. We replicate these findings in a second experiment and show that the selective encoding of information in the alpha range is not due to visual entrainment. These findings are consistent with the emerging idea that alpha oscillations may be a signature of predictive visual processing, and are further evidence that the visual system predictively encodes the location of moving objects.

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Structure and knowledge effects on amodal completion in early visual cortex and lateral occipital complex

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The brain seems to fill-in missing information in the sensory input when objects are partly occluded, referred to as amodal completion. In the literature it is disputed whether amodal completion merely relies on local cues dealing with structural aspects of the occluded object or also on contextual cues in which familiarity plays an important role. To shed some further light on these questions, we reused occlusion stimuli from a previous EEG study, containing well-known objects (fruits and vegetables) of which the middle part was occluded. The perceptual completions of these stimuli could follow two basic cues. In those compatible with the structural cue the visible parts could be connected by linear interpolation of their contours. In those compatible with the knowledge cue the

completion followed expectations about the object. We measured brain activity with fMRI using a rapid event-related repetition suppression paradigm, which results in higher activity when two consecutive stimuli are dissimilar, while lower activity is observed when two consecutive stimuli are perceived as similar. We performed a region-of-interest analysis in early visual cortex, that is V1, V2, V3, and the lateral occipital complex (LOC). Preliminary results confirmed the previous EEG findings that stimuli compatible with the structural cue show activity already in early visual areas, and that those compatible with both structure and knowledge show activity in both early visual cortex as well as LOC. In summary, the results show that amodal completion can result from both structure and knowledge cues, reflected in different neural patterns.

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The Influence of an Irrelevant Task on Gestalt Accentuation

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Gestalt principles are one of the most amazing types of evidence demonstrating top-down processing. It underlies our completion ability of partially displayed objects or images, based on environmental clues or innate cognitive skills. These principles typically involve automatic processing. In the present study, we aimed to examine the influence of an irrelevant task on the automaticity of the Gestalt principles. In two experiments we ran a Stroop-like task: participants were required to respond to the color component of stimuli, while ignoring their semantic meaning. The two experiments differed by the stimuli graphic structure: While in Exp. 1 the stimuli were presented explicitly, in Exp. 2 the stimuli were sliced horizontally into 4 slices. Analysis of RTs suggested that participants processed the meaning of the stimuli in both experiments. That is, in both experiments RTs in incongruent trials were slower than those in the congruent trials. Moreover, all participants reported correct immediate stimuli perception\ comprehension. These are clear evidence supporting gestalt validity. However, RTs in Exp. 2 were slower than those in Exp. 1. This RT slowdown pattern suggests a time-consuming process needed for segregation of the combined stimuli properties: the stimuli semantic meaning (the irrelevant task) and the colors (the relevant task). It indicates investment of attentional resources. These findings contradict earlier Gestalt indications, stating that segmentations such as figure - ground, occur without focal attention. The results support a new Gestalt principle of figure-ground segregation termed "accentuation".

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Statistical learning facilitates access to awareness

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The capacity of visual awareness is limited compared to the large amount of visual information that enters our eyes. The visual world is structured, however, and the influx of information entering our eyes is subject to statistical regularities. Decades of research have shown that observers can capitalize on these regularities to benefit behavior. Here, we ask whether statistical regularities modulate the very contents of our conscious perception, by favoring conscious access of highly probable visual events. Specifically, we asked whether high-probability (versus low-probability) objects gain priority in accessing visual awareness. In two experiments, we manipulated the probability of a target stimulus appearing at a specific location (left or right of fixation; Experiment 1), or with a specific feature (a triangle, pointing up or down; Experiment 2). Target stimuli were initially rendered invisible through continuous flash suppression, and participants were required to determine as fast and accurately as possible the orientation (Experiment 1) or location (Experiment 2) of target stimuli. We interpret response times to initially suppressed stimuli as an index of the priority of these stimuli for accessing visual awareness. Results show that the speed of targets accessing visual awareness was significantly enhanced when the target was presented at a high- versus low-probability location, or contained a high- versus low probability feature. These findings indicate that the human visual system can make use of statistical regularities embedded in visual information to regulate conscious access, thus prioritizing highly probable events over unlikely events.

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Interaction between CFS mask and target across spatial frequency and orientation

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Continuous Flash Suppression (CFS) has become one of the most popular tools in the study of visual processing in the absence of conscious awareness. Studies use different kinds of masks, like colorful Mondrians or random noise. Little is known if masks suppress stimuli better if the masks are similar to the stimuli. In our previous experiment we showed evidence for interactions between masks and stimuli, in the domain of orientation alignment; Here, we investigated whether the enhanced suppression due to orientational alignment is limited to overlapping spatial frequency bands between mask and target.

We designed a b-CFS experiment with feature-reduced targets and masks in order to investigate possible effects of feature-similarity or -orthogonality. Masks were pink noise patterns filtered with both orientation and spatial frequency band pass to generate a strong directionality within a limited frequency band (high, middle and low). Target stimuli were Gabors varying systematically in their orientational and frequency band alignment with the masks.

Implementing both masks and targets as grayscale (luminance) patterns, the alignment orientation between targets and masks significantly affected suppression duration $F(4,96)=39.596$, $P<0.001$. Overlapping frequency band pairs had longer suppression duration than non-overlapping $F(18,432)=25.729$, $P<0.001$. There was significant suppression between mask-target pairings of both identical and different frequency band.

We conclude that mask-target interactions exist in Continuous Flash Suppression, and the human visual system can use orthogonality within a feature dimension or across feature dimensions to facilitate the breaking of the CFS.

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Can perceptual completion take place in the absence of visual awareness?

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Objects in the environment are often partly occluded. The visual system seems to fill in the missing information – a process called amodal completion – based on features at or near the occlusion boundary (local completion) or on the characteristics of the whole object (global completion). We investigated the involvement of visual awareness in amodal completion, specifically, whether visual awareness plays a differential role in local versus global completion. We used a primed shape discrimination and a modification of the Color-Opponent Flicker technique to render the prime invisible. In three experiments, participants were presented with a partly occluded prime followed by a clearly visible target. Each prime contained perceptual cues that potentially support local completion (good continuation) and global completion (object symmetry), which diverge to different completions. The target corresponded to the shape that could arise as a result of a local or a global completion of the prime. For each experiment with an invisible prime we conducted a version in which the prime was visible. Results with the invisible primes showed some indication of local completion in the absence of visual awareness, but only for the occluded prime that generated a single (local) completion when visible (Experiments 1a, 1b). No priming, either local or global, was observed in the absence of visual awareness for occluded primes that generated multiple completions – global and local – when visible (Experiments 2a, 2b; 3a, 3b). These findings suggest that amodal completion is unlikely to occur in the absence of visual awareness.

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Talk session 25. Low Level Vision

Deep reinforcement learning for evaluation and optimization of prosthetic vision

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In the near future, neuroprosthetic visual implants may provide a promising opportunity for the restoration of basic visual perception in blind people. Through the implantation of many electrodes that target neurons in the visual pathway, visual information (captured by a camera) can be directly conveyed to the brain, bypassing the eyes. With electrical stimulation, a visual percept can be elicited that looks like a pattern of localized light flashes, or 'phosphenes'. Because of the limited resolution compared to natural vision, this artificial percept can capture only a simplified visual representation, containing just the most relevant visual features of the surroundings. A variety of scene simplification strategies have been proposed in the previous literature, such as edge detection or depth-based processing, but the results are inconclusive. Notably, the achieved

results highly depend on the contextual parameters such as the task, the environment, or even the characteristics of the implant. In our research, we are developing more automized and adaptive optimization methods. Besides non-invasive mixed reality (XR) simulations of prosthetic vision in sighted individuals, we propose computational experiments with virtual agents as a valuable addition to the toolkit of the prosthetic engineer. Our preliminary results indicate that task-based informativeness of prosthetic vision can be quantitatively evaluated using reinforcement learning in virtual environments. Furthermore, they indicate that specific image processing parameters, such as the threshold for edge detection can be automatically optimized for arbitrary contexts. Our proof-of-principle experiments demonstrate the potential of computational experiments for inexpensive and tailored optimization of prosthetic vision.

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A biologically plausible phosphene simulator for the optimization of visual cortical prostheses

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As per June 2020, there are around 36 million blind people in the world. This number is expected to increase to 115 million in 2050. For some blind individuals, a promising solution to restoring vision are cortical visual prosthetics, which convert camera input to electrical stimulation of the cortex to bypass part of the impaired visual system. Electrical stimulation in the primary visual cortex has been found to produce dots of light in the subject's vision, called phosphenes. By evoking phosphenes in the right patterns, prosthesis wearers can be shown a representation of the outside world. As this representation has a limited resolution, visual prosthetics will need to rely on intelligent image processing algorithms that filter meaningful information from the visual surroundings. To optimize these processing strategies, non-invasive simulated prosthetic vision (SPV) can be used with sighted subjects or computational models. However, most SPV studies use highly simplified models of phosphene generation, limiting their validity for real-life applications. In this project, we developed a fast and fully differentiable phosphene simulator that transforms electrode stimulation patterns into biologically plausible representations of what the prosthesis wearer is expected to see. Relevant characteristics are the retinotopic organisation and cortical magnification of the visual cortex. Moreover, previous experimental results showing the quantitative effect of stimulation strength, duration, and frequency on phosphene size and brightness as well as the temporal characteristics of phosphenes are incorporated in the simulator. Preliminary results show the usability of the simulator for both computational applications as well as behavioural experiments.

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Activity in hMT+ Reflects the Effect of Spatial Attention on Surround Suppression

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A visual neuron's activity may be suppressed by iso-oriented stimuli presented outside of its classical receptive field, which is termed as surround suppression. The effect of the spatial extent of attention on surround suppression, however, is not fully understood. Here, we investigated how increasing the extent of spatial attention affects surround suppression using psychophysical methods and fMRI. A central grating (diameter: 1.5°) with 98% Michelson contrast was presented either alone or surrounded by an annular grating (width: 9.2°) with a 1.3° gap between them. Under two attention conditions, participants (N=10) were instructed to either limit their attention to the central grating (Narrow Attention, NA) or to both gratings (Wide Attention, WA). Critically, drift directions of the central and annular gratings could be the same or opposite. First, in a behavioral experiment, we showed that surround suppression was significantly stronger under the WA condition compared to NA for the same direction trials. Next, using a mixed fMRI design, we found that neural suppression in the middle temporal complex (hMT+) increased as the extent of spatial attention increased in the same direction trials, but not in the opposite direction trials, consistent with the behavioral results. These findings unveil the critical role of spatial attention on surround suppression and show that hMT+ is a likely origin of the effect.

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The influence of context on perceptual inferences

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Perception of visual stimuli does not happen in a vacuum – it is heavily influenced by surrounding context. For example, when reproducing the orientation of a grating presented among differently oriented flankers, observers' judgements are biased toward the mean orientation of the flanking stimuli. Many studies have investigated contextual influences for such artificial displays, but it remains unclear how perception of elementary visual properties such as orientation are affected by complex naturalistic stimuli. Here, we had participants judge the orientation of a small 'probe' patch taken from a larger naturalistic image and compared their accuracy when the probe was pre-cued with the larger naturalistic image from which it came, or an equivalent region of pink noise. Observers (N=20) were more accurate in their orientation judgements when pre-cued with the naturalistic image, suggesting successful integration of contextual information. To test the extent to which the influence of contextual information was driven by the low-level orientation information in the pre-cue specifically, we introduced a pre-cue rotation manipulation. Observers' probe orientation judgements were biased toward the orientation of the contextual cue, suggesting a strong contextual influence attributable to low-level features. This influence was apparent even with brief pre-cue presentation durations as short as 125 ms, increased in magnitude with longer presentations, until finally plateauing after approximately 500 ms. Together, our findings suggest that immediate naturalistic contextual information is incorporated rapidly, and the low-level features of such context play a key role in biasing our subsequent perceptual interpretations.

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Saccades' trajectories deviate from optimally informative visual features

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The path of a saccade to a target can be influenced by the presence of a distractor, which can induce a curvature of the trajectory away or towards its location. Previous research has shown that the more salient the distractor, the more pronounced the curvature of the saccade.

Here, we exploit this phenomenon to investigate the effective saliency of some visual features, predicted by a constrained maximum-entropy model to be optimal or non-optimal information carriers in fast vision, by using them as distractors in a saccadic task.

Participants performed vertical saccades towards a target randomly presented 7° above or below the initial fixation, while one visual distractor could randomly appear (for 25ms) with variable delays. We measured the saccadic curvature induced by model-predicted optimal and non-optimal features and compared it to that induced by control distractors with different luminance.

Results show that optimal features evoke a larger saccadic curvature than non-optimal features. The magnitude and direction of the deviation changed according to the distractor-to-saccade onset asynchrony (DSOA). When the DSOA was large (from -300 to -200ms), deviations away from the distractor were maximal and decreased as the DSOA increased. At the smallest DSOA (from -150 to -50ms), saccades deviated towards the target. Effects were similar to those found with high-luminance vs. low-luminance distractors.

Thus, visual features predicted by the reference model to be salient in fast vision interfere with the programming of saccades. Also, visual saliency determined by the specific spatial structure of optimal features is comparable to luminance-based saliency.

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Inner-outer asymmetry in the Eriksen flanker task

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Interference from task irrelevant visual stimuli ("flankers") has been studied through the Eriksen flanker task and visual crowding, among others. However, despite obvious similarities between the two approaches, they have been studied predominantly separately. In order to explore possible links between them, we examined whether a well-established diagnostic property of crowding, stronger crowding by the outer (more peripheral) compared to the inner (more foveal) flanker, is also observable in the Eriksen flanker task. Specifically, using an orientation categorization task, we manipulated flanker (1) congruency (congruent/incongruent), (2) location (in/out) and (3) spacing (close/mid/far), relative to the target. Analogous to findings in crowding, the congruency effect (better performance in congruent compared to incongruent trials) for categorization accuracy decreased with increasing target-flanker spacings and this was more pronounced for the outer flanker. In contrast, for reaction times, congruency effects were stronger for the inner compared to the outer flanker, and their strength was not modulated by spacing. This unexpected finding could be accounted for by recent reports that the inner flanker is more often confused with the target than the outer flanker in crowding tasks. Thus, there are clear qualitative differences between the pattern of results for the two measures (accuracy and reaction times) of inner and outer flanker interference. These findings suggest that inner and outer flankers differ in the extent of interference they produce at visual processing and decision making stages, with outer flankers interfering most at the

visual processing stage and inner flankers interfering more with decision making.

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Talk session 26. Depth & Stereo

Do JNDs Measure Uncertainty in Depth Discrimination?

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The visual system relies on numerous depth cues when interpreting the 3D layout of the world. Measuring the depth discrimination threshold, known as the Just-Noticeable Difference (JND), is a common method for evaluating how the visual system processes and integrates distinct cues. Bayesian inference models suggest that the JND reflects the uncertainty in the depth estimate. Despite correctly predicting a reduced JND from integrating multiple signals, we put forth a radical reinterpretation of the JND which supports previous data while forming new predictions. Instead of uncertainty, the JND measures the cue-strength as defined by the Intrinsic Constraint (IC) model. IC proposes that physical depth is deterministically mapped to perceived depth through linear functions unique to each cue and viewing condition. The function slopes, termed cue-strengths, determine how sensitive the visual system is to depth changes. Here, we present two lines of evidence supporting this relationship between the JND and cue-strength. 1) In two experiments, we measure the cue-strength through an absolute depth estimation task and the JND in a 2-IFC discrimination task. Results show a clear relationship between the JND and the cue-strength. 2) In a novel method, we measured the JND in a 2-IFC task where the fixed standard stimulus and the varying comparison stimulus differed in cue-strength. As predicted, the JND only depended on the cue-strength of the comparison stimulus, rather than the uncertainty of both stimuli. We conclude that discrimination thresholds do not measure the uncertainty of 3D estimates but are an indirect measure of cue-strength.

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Real-world object size inferred from scene context sharpens object representations in visual cortex

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Our ability to recognize objects is strongly facilitated by scene context. Consequently, we are more likely to recognize an ambiguous object (e.g., a car) when it is placed in a typical context (a road) than when it is placed outside of context. Recently, such facilitatory effects were shown to sharpen neural responses in object-selective visual processing regions. What are the contextual cues that lead to such facilitation effects? Scenes do not only predict the identity of an object (a road is likely to contain a car), but also its appearance (e.g., a car is about as wide as the lane on which it's driving). Here, we investigate how predicted object size, as inferred from scene context, influences object processing. In a series of behavioral studies (N=240), we found that coherently sized objects (e.g., visually small objects presented far away) were more easily recognized than incoherently sized objects (the same small objects presented nearby). Using fMRI (N=35), we found that this behavioral benefit was reflected in visual cortex responses. We trained linear classifiers to distinguish between clearly visible animate versus inanimate objects, presented in isolation in separate training runs. These classifiers successfully decoded the animacy category of visually degraded objects within scenes, throughout visual cortex. Importantly, size-congruent objects yielded substantially better decoding performance than size-incongruent objects in object-selective cortex, but not in early visual cortex. We conclude that the expected real-world size of an object, as inferred from scene context, contributes to object recognition and sharpens object representations in visual cortex.

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PTVR : a user-friendly open-source script programming package to create Virtual Reality experiments

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Using Virtual Reality (VR) to investigate visual processing is a growing trend due to the high scientific potential of VR (allowing experiments in highly controlled environments and ecological scenarios), and to the increasing power of ever cheaper VR headsets. However, implementing VR experiments requires non-trivial programming skills that are long to learn. Alleviating this implementation process is thus a great challenge and should be guided by the success of existing script programming packages used to display stimuli on 2D monitors (e.g. the free, and open-source package PsychoPy). A step in this direction

was achieved by the «Perception Toolbox for Virtual Reality» (PTVR) package (first presented at ECVP 2018) with the ambition to follow the same Open Science philosophy as PsychoPy but applied to VR. At ECVP 2022, we propose a consolidated and extended version of PTVR with many new features. We will describe, from scratch to finish, how any researcher familiar with Python programming can create and analyze a sophisticated experiment in VR with parsimonious code. A 3D visual search experiment will serve to illustrate the easiness with which: (1) 3D stimuli are positioned thanks to different coordinate systems, (2) online positions of the head, gaze, or remote controllers are used to point at the target interactively, (3) all the data are accurately recorded across time. We will also present the resources allowing researchers to quickly learn PTVR, notably hands-on demos included with PTVR and a website (https://ptvr.inria.fr/) offering an extensive user manual.

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The role of the horizon in the perception of ground plane slant

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The ability to judge whether or not a surface is flat and horizontal is crucially important for many locomotor activities. As terrestrial creatures, we live on a more-or-less flat and horizontal ground plane - the surface of the earth - but the visible horizon of natural scenes does not always coincide with the geometric horizon of the earth. As a consequence, our perception of the slant of the ground plane surface is sometimes incorrect (eg the Electric Brae). We investigated two factors involved in these misperceptions: (i) the height of the visible horizon in the scene and (ii) the left-right tilt of the visible horizon. In the first experiment, observers were asked to judge the direction (uphill/downhill) and degree of ground plane slant. In the second, observers adjusted the orientation of a circularly-apertured visual image until the scene appeared to be correctly oriented. Images of natural scenes were projected onto a large-field screen and included both open landscapes and woodland scenes with trees and other features constrained by gravity (i.e. orthogonal to the horizontal plane). The height of the visible horizon produced systematic errors in observers' judgements of both uphill and downhill slant, even when water surfaces were present. There were also consistent errors in judgements of the left-right tilt of the scene but these effects were substantially reduced when trees were present. Overall, our results show that ground plane judgements can be significantly affected by both the height and tilt of the visible horizon.

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Cue combination with augmented sensory information: learning to combine familiar and novel cues to depth

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Depth perception relies heavily on the integration of multiple different cues, such as stereo, motion or texture, into a coherent representation. Typically, the ways in which these cues are used in conjunction to infer depth is learned over years of experience during development. However, whether the functional features (precision enhancement, re-weighting, fusion) of cue combination are restricted to familiar (native) cues, or emerge similarly with completely novel cues to depth with minimal training is still unclear. This study presents data from a depth discrimination task that measured these properties of cue combination for native and augmented multisensory cues. Over the course of four sessions, participants were exposed to three different depth cues that were presented either alone, in combination as a native-native (binocular disparity, size/texture) pairing, or as a native-augmented pairing (binocular disparity, auditory pitch). Preliminary data from six participants suggests precision increases, re-weighting and partial fusion in both types of cue pairings, with stronger effects for native-native than native-augmented pairings. This suggests that all three functional features of cue integration can be readily established in adulthood and with minimal training, however, the efficiency of each process may depend on the amount of experience. While more data will be required to draw definite conclusions, this first direct within-participant comparison of familiar and novel cue combination will provide a testbed for comparing the cognitive and neural mechanisms involved in native and augmented perception. Better understanding mechanisms for efficient cue combination via alternative cues can inform enhancement and rehabilitation of human perception.

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Surface Attitude Judgements with Haptic and Visual Response

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The perception of surface orientation can be probed by a variety of methods, but little is known about how judgements depend on the method. Here, we cross-validate multiple measurement methods to better understand how they relate to each other.

We generated synthetic textures comprising randomly orientated squares rendered onto slanted planar surfaces. Stimuli were viewed monocularly and binocularly with and without disparity, through a 12° circular aperture. We explored four modes of response: 1) an unseen haptic paddle, 2) a visible haptic paddle, 3) a 2D gauge figure, 4) a 3D gauge figure, 5) slant and tilt dial indicators in the plane of the screen.

Tilt judgements were precise and accurate for all methods. For slant, observers were about equally sensitive and precise when using the visible paddle, gauge figures and dials, but were significantly less sensitive and precise with the unseen paddle. Sensitivity was especially poor when using the unseen paddle to judge stereoscopic surfaces. While the paddle and gauge figures produced response gains less than 1, the slant dial generated a gain greater than 1. Slant bias was negative for paddle methods, positive for gauge figures. The dial method overestimated high slants but underestimated low slants.

While observers are adept at reporting tilt with all methods, reporting of slant is less accurate and precise and depends strongly on the method of response. The unseen haptic paddle generated the worst results. Sensitivity and precision are similar for the four other methods but gain and bias vary by method.

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Poster session 28. Depth & Stereo

Surface orientation affects sensitivity to disparity-defined variations in depth

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Our sensitivity to depth from binocular cues is limited by the estimation of absolute binocular disparity via a process of cross-correlation. Since variations in disparity appear to be represented relative to a local surface coordinate frame, we assessed the effect of the rotation of a surface in depth on observers' sensitivity to variations in its depth structure. On each trial, observers were presented with two random dot stereograms. In the threshold condition, one depicted a planar surface, rotated away from the frontoparallel plane about a horizontal axis through an angle of between 0 and 40 degrees. The other depicted a surface with a horizontal sinusoidal corrugation in depth, with a spatial frequency of 0.5 cycles/degree, with the whole surface rotated through the same angle as the planar comparison. Their task was to detect the corrugated surface. In the suprathreshold condition, two corrugated surfaces were presented, with either the same or opposite rotations about a horizontal axis, and observers judged which had the largest corrugation amplitude. For both threshold and suprathreshold judgements, discrimination thresholds rose as the surfaces were rotated from 0 to 40 degrees. For the suprathreshold task, thresholds were greater when the two surfaces were rotated in opposite directions. These results show that sensitivity to local depth variations is not completely invariant to surface orientation, and cannot be explained solely by the limits imposed by cross-correlation.

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The Role of the Depth Dimension in 3D Visualizations for Dense Data Understanding

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Visual attributes, such as size, shape, or colour, play a crucial role in the interpretation of data visualizations and can be used to represent the data at different scales. On 2D displays, human viewers then perceive the differences between scales based on such visual attributes. While it can be challenging for human to interpret data in dense visualizations in 2D, the additional depth dimension offered by 3D could make some aspects of data more visible.

To analyze the potential impact of depth perception on dense data visualization, we developed a novel visualization method and visualized dense COVID-19 time-series data of four European countries (France, Germany, United Kingdom, and Turkey). In our novel visualization, we aimed to increase the visibility of individual data points to

ease visual perception and visualized daily total cases in the depth dimension.

We conducted a user study with 20 participants where we compared a conventional 2D visualization with the proposed novel 3D visualization method for COVID-19 data.

The results show that the novel 3D visualization method facilitated understanding of the complexity of COVID-19 case data and decreased misinterpretations by 40%. Overall, 13 out of 20 participants preferred to see the COVID-19 data with the proposed method. Participants' comments on the novel visualization method revealed that the increased visibility of individual data points decreases the cognitive load of the participants, which might explain the outcome.

The results of our work identify that the depth dimension offered by 3D visualizations can assist users in understanding dense data.

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Classification images for stereoscopic aerial photographs: binocular disparity is used more by expert- than novice-surveyors when discriminating hedges from ditches

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We utilize the Classification Images technique to explore visual expertise comparing remote sensing surveyors with novice observers. In a further innovation, we generated classification images for luminance and binocular disparity simultaneously. Six expert surveyors trained in assessing 3D stereoscopic aerial imagery lit from below, and six novices with comparable stereoacuity classified stereoscopic aerial images representing centrally located hedges and ditches over 10,000 trials. Images were heavily masked with visual noise that varied in both luminance and disparity. Ditch and hedge images were presented in separate blocks but with reversed disparity on 50% of trials such that hedges became ditch-like and vice versa. They were also flipped vertically on 50% of trials thus flipping the light source. Classification images were generated by accumulating the noise samples associated with ditch and hedge responses respectively, and subtracting one from the other. Classification images for both luminance and disparity had a peak at the location of the geographic features, which was accompanied by negative side-lobes. Experts made more use of disparity cues than novices. Both groups used luminance contrast to support the task, consistent with the dark-is-deep assumption, but experts sampled luminance from a wider area. While most novices demonstrated a bias towards lighting from above in their response patterns some experts demonstrated lighting from below, consistent with their training. The classification image technique may be complementary to other methods, such as eye tracking, for the study of visual expertise and unlike other methods can reveal the use of binocular disparity as a cue.

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How do we encode binocular visual direction?

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The visual brain must determine the depth and visual direction of objects in space relative to the viewer. The location from which judgments of direction are made – called the egocentre - sits approximately midway between the left and right eyes. Remarkably, degrading the input to one eye alters behavioural estimates of visual direction. Competing theories have proposed that either the egocentre location shifts towards the eye receiving the more visible image, or binocular visual direction is determined from a weighted average of the oculocentric directions. To resolve this issue, participants (N=6) completed a binocular horizontal alignment task between two vertically-separated, Gaussian-windowed, one-dimensional noise patches presented at different stereoscopic depths (range $\pm$60 arcmin) relative to a central binocular fixation marker. The contrast ratio between the left and right images for the upper noise patch was varied, but was fixed for the lower patch. Participants adjusted the horizontal location of the lower patch until it appeared aligned with the upper patch. To investigate the visual features used to make judgments, the noise samples for the upper and lower patches were either correlated or uncorrelated on each trial. Alignment estimates were similar when the noise patches contained correlated or uncorrelated stochastic samples, suggesting participants relied on the contrast envelope of the stimuli. Crucially, the pattern of alignments across the depth range was consistent with models in which binocular visual direction is computed by a weighted average of the monocular directions and favours coarse scale information.

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Correct focus cues improve the perceived realism of depth in stereoscopic images

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Virtual Reality aims to convey 3d scene structure as compellingly as possible. Although stereoscopic imagery results in a vivid sense of depth, perceived realism of 3d space has been shown to reduce as the depth separation between stimulus elements increases. A possible reason is that conventional stereoscopic displays present images on a single focal plane, resulting in increasingly incorrect focus cues (stimulus to accommodation; retinal blur gradient) as depth separation increases. Using a multiple-focal-planes stereoscopic display we compared perceived realism of 3d space in conventional stereoscopic images, and equivalent images presented with correct focus cues. The stimuli were random-dot stereograms depicting two planes separated in depth. The depth separation between planes varied across trials. Participants (N=15) judged which of two stimuli, presented consecutively, contained the more realistic 3d separation in a two-interval forced-choice task. Participants were instructed to look between near and far planes during the task. All possible pairwise combinations of depth separation and focus-cue condition were presented. Thurstonian scaling was used to derive relative realism scores in each case. Perceived realism was consistently higher with correct focus cues than with conventional 3d stereoscopic presentation. Moreover, when focus cues were correct, perceived realism did not decrease with increased depth separation, but instead remained constant. Our results indicate that correct focus cues improve the perceived realism of 3d space in stereoscopic images, and so could potentially contribute to Virtual Reality that is more compelling.

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Vertical shear disparity processing in depth for inclination perception and cyclovergence

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Introducing vertical shear disparities into binocular images causes a frontal stereoscopic surface to appear inclined in depth about a horizontal axis and evokes cyclovergence. Previous studies have shown that the apparent inclination depends on the mean vertical shear disparity pooled over a large area of the visual field. Vertical shear disparity arises uniformly over the whole visual field due to binocular torsional eye misalignment, so pooling over the whole field could enable the visual system to estimate the whole-field vertical shear reliably. However, previous studies only used stimuli in the fixation plane, so it is not known whether/how vertical shear disparities are used at different depths. Here we examined whether vertical shear disparities in surfaces at different depths are effective in inducing apparent inclination and evoking cyclovergence, and whether vertical shear disparities are pooled across depth planes. Stimuli were stereoscopic surfaces (approx. 70deg.) comprising arrays of texture elements. The surfaces contained vertical shear disparities (±1.5deg.) and were presented at a range of depths (horizontal disparities, ±40 arcmin) with respect to fixation. We found that vertical shear disparities in a stimulus at a different depth from fixation are effective in evoking cyclovergence and inducing apparent inclination in a fixated central array containing no measurable vertical shear disparities. To investigate whether vertical shear disparities are pooled over depth we presented two superimposed arrays at different depths, each with a different vertical shear disparity. Results suggest that vertical shear disparities are averaged over a limited range of depths for inclination perception.

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Remapping of Peripersonal Space in Virtual Reality: An Exploratory Study

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It is well known that the space around us can be divided into two categories based on our ability to directly interact with the environment: the peri- and extra-personal space. In humans the border between the two can be experimentally measured with the use of a visuo-tactile detection task. However, this border is not static and the transition between near and far space can be modulated, with a short-period of tool-use training causing an enlargement of the peripersonal space. Yet, it is still unclear which property of the training triggers such an expansion and whether the peripersonal space holds the same properties in immersive virtual reality environments. In this study we attempted to reshape the peripersonal space in virtual reality with the use of different types of training. In particular, we compared the effect on the extension of peripersonal space after a training period in which subjects interacted with a target in the far space either through a hammer (direct contact) or by shooting a gun (undirect target contact). On top of this, the properties of the virtual reality allowed us to test the effect of different kinds of feedback during the training, with participants receiving both visual and

proprioceptive feedback or visual only. Our preliminary results suggest that the kind of feedback is a key component for the modulation of the border of the peripersonal space in virtual reality and provide insight on the mechanisms regulating its extension also in ecological settings.

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New Measures of Stereoscopic Vision: Assessing Reliability and Validity

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There is renewed interest in developing specific trainings to enhance or restore binocular depth perception in persons with poor stereopsis. To measure training effectiveness, it is important to capture small stereoacuity changes with measures that are not prone to learning over repeated testing. However, most clinical stereotests do not capture small changes, are contaminated by monocular or binocular non-stereoscopic cues, and learning is rarely tested over multiple sessions. Thus, there is a need for new tests that are sensitive only to binocular stereovision and stable over multiple sessions. We evaluated the concurrent validity of two new stereoacuity tests: eRDS, a global dynamic random dot stereogram (dRDS) test, and the Vivid Vision stereotest, a local stereotest performed in a virtual reality environment. We compared these tests to a "gold standard": Asteroid, a global dRDS stereotest presented on a tablet. We also evaluated the reliability of the tests over 6 sessions. eRDS was effective at measuring thresholds smaller than 10 arcsec and showed a correlation of 0.48 with the Asteroid test. Although the test-retest reliability was excellent (Spearman correlation between 0.84 and 0.91), Bland-Altman analyses revealed learning across the first three sessions. Vivid Vision could not capture thresholds under 20 arcsec and had a correlation of 0.27 with Asteroid. Although test-retest reliability was weaker (between 0.35 and 0.74), Bland-Altmann plots demonstrated good stability with no learning between sessions. Future work should aim at improving those new tests, to reach a precise and stable standard for measuring changes in stereovision following training.

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Poster session 29. Computational Modelling

Interaction between colour and form in Vision Transformers

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Previously, it was hypothesised that colour and form are processed independently. However, the current view indicates a strong mutual dependency between these two visual attributes. Here, we studied the colour-form relationship in Vision Transformers (ViT) - a deep learning model that processes the input sequence with attention mechanisms. We focused our investigation on CLIP (Contrastive Language-Image Pre-Training), a neural network trained by OpenAI on a variety of image-text pairs. First, we examined the colour categories in this model with zero-shot learning (i.e. no training). We input the network with images that consisted of a coloured object presented on an achromatic background. This exercise was repeated for thousands of natural objects and geometrical shapes for all the 320 Munsell chips that are often used in psychophysical experiments of colour categorisation. The network output (a colour term from a set of eight colour names) was compared to the basic universal colour terms (Berlin & Kay, 1969; Sturges & Whitfiel, 1995). The results show that the model faithfully captures the human colour categorisation (about 90 to 95% accuracy). We further systematically investigated the impact of the object's form on border colours (belonging to two or three categories). The analysis suggests an intertwined colour-form interaction as a function of background luminance and shape properties (such as spatial frequency, orientation, concavity, etc.). We further extended this analysis to a 2AFC colour discrimination task measuring the hue- and saturation-sensitivity of the network. Overall, we put forward language-image transformers as a powerful framework to study colour perception.

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Solving a difficult figure-ground segmentation problem in sedimentary rock photomicrographs using a fully automated algorithm combining Marr's Raw Primal Sketch and a Magno-Parvo Additive model

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The Magnocellular channel provides, alongside motion information, a snapshot view of the external world,

whereas the detailed view requires Parvocellular intervention. The initial scouting by Magno, leads to the Marr-proposed Raw Primal Sketch at low-level which determines to what extent further detailing by Parvo is required to achieve the mid-level vision task of segmentation. The above hypothesis has been used to set up a Magno-Parvo Additive (MPA) model, using three Gaussian functions, representing the excitatory, the inhibitory, and the disinhibitory responses respectively. A difficult problem in computer vision has been successfully addressed through this automated algorithm.

Segmentation of sandstone grain from its surrounding matrix/cement in the thin section is a crucial step for computer-aided mineral identification and sandstone classification. In the photomicrographs it is also difficult to distinguish between adjacent grains apart from performing figure-ground type grain-matrix classification that itself is often ambiguous. Although the trained Geologist's eye can manually do the job successfully, the automated solutions that exist in literature are not robust against sandstone petrography's varied pattern.

The proposed automated segmentation algorithm calculates successively for each of the three color channels in the initial Magno filtered image, a) the Laplacian of Gaussian; b) the MPA output using a parameter derived from (a); c) figure-ground segmentation on the final colors-concatenated image obtained from (b), using a standard machine learning technique. It is found that the method is robust, and can possibly be extended to other difficult machine vision problems too.

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A computational model of hand perception

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We use our hands to manipulate and explore objects around us. Judging the spatial properties of objects requires a three-dimensional internal representation of the hand as well as the multisensory integration of visual, tactile, and proprioceptive information (Lutz & Bensmaia, 2021).

The brain needs to integrate proprioceptive cues about joint angles with phalanx length, to dynamically track the position of fingertips and joints. Given the uncertainty associated with sensory feedback, the brain likely relies on internal representations about the structure of the hand and fingers. However, the neural computations underlying this process have never been addressed. We propose a Bayesian model of how the brain integrates sensory feedback with prior knowledge of hand structure to construct an internal representation of the hand in three-dimensions. We propose that this process involves probabilistic coordinate transformations of proprioceptive information and priors over finger length and flexion. One specific prediction of the model entails that hand perception is biased towards the prior information over hand structure – which may finally explain well-known biases in finger localization (Longo & Haggard, 2010). Furthermore, this multisensory representation integrates visual information about hand posture, a transformation that mitigates the proprioceptive biases. We will test model predictions using a novel virtual-reality-based set-up to probe fine-grained biases in hand perception in three dimensions, and present the results of the experiments that are currently underway.

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BLresnet: A novel sequential deep neural network to investigate human dynamic object recognition

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Human object recognition closely relies on the dynamic and sequential nature of vision. This is illustrated in the improvement in perceptual accuracy with longer presentation durations for both images and image sequences (i.e., rapid serial visual presentation (RSVP) tasks), or the detrimental effect of backward masking. Yet, most computational models of object recognition only account for static images, presented in isolation. This includes deep convolutional neural networks, which do not account for the dynamic nature of vision. Previously, we have shown that a lateral recurrent model (BLnext) can predict human sequential object recognition on a RSVP task of up to 80 ms/image but that it fails at the slowest rates (160 ms). Here, we combine the computational benefits of residual connections with those of lateral recurrence into a new model (BLresnet) and find that such a model is not only more stable over time, but also achieves higher image classification accuracy than BLnext. By contrasting both BLnext and BLresnet predictions of human behavior across three different tasks, we observe that (1) BLresnet better explains reaction times on an animacy discrimination task, (2) covers a wider range of RSVP image presentation durations, now including the slowest rates, and (3) mimics the detrimental effect of visual masking. Altogether, our results present BLresnet as a promising computational model for understanding human dynamic object recognition.

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CNN-based search model underestimates human attention guidance by simple visual features

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Traditional visual search models assume that attention is guided by a relatively small number of simple features like brightness, color, size, and orientation. Recently, Zhang et al (2018) proposed an interesting model of attention guidance that uses complex visual features learnt by convolutional neural networks (CNNs) when trained for object classification. The model accounted well for human eye movements and reaction times when searching for a target among natural objects, or in cartoon pictures. However, this model was not tested with simple classic search tasks.

I adapted the above model for search experiments with accuracy as the measure of performance and applied it to simple feature and conjunction search stimuli from our earlier experiments with human observers. The simulations revealed that CNN-based search model considerably underestimates human attention guidance by simple visual features.

A simple explanation of the observed inefficiency might be that the model has no bottom-up guidance of attention. However, assuming that calculation of saliency is a regular component within the feature extraction network in biological vision, we can suggest that CNNs trained for object classification have not learnt to calculate bottom-up saliency of visual features required for human-like guidance of attention.

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Modeling private and shared tastes in facial preference judgments

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Facial preference judgments are multifaceted and known to vary across individuals and cultures. Although these idiosyncrasies in facial preference have repeatedly been documented in well-controlled psychological experiments, few studies have attempted to clarify the multidimensional contribution of realistic facial features to private and shared tastes in preferences. Recent technical advances have enabled the generation of highly realistic facial portrait photos indistinguishable from real human faces. We used such images generated using StyleGAN2 to quantify private and shared tastes in facial preference in a task that simulated a dating app. In this online study, 80 German-speaking participants (40 female and 40 male) should imagine that they are looking for an ideal partner in an online dating app. They viewed 250 face images of their preferred gender, and decided whether they liked or disliked a person according to their private taste. Their preference decisions were analyzed with a data-driven computational model to quantify the relative contribution of private and shared tastes on facial preference decisions and to identify visual features driving these two types of tastes. Our results showed that private taste is as impactful as shared taste in facial preference judgments, and a variety of visual features that appear on real faces - including expressions, fine-grained skin textures, and hairstyle - affect these two types of facial preferences. Using highly realistic artificial faces generated with StyleGAN2, we could overcome drawbacks of homogeneous facial stimuli such as low photorealism, and refine a data-driven computational model of facial preference.

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What is the 'correct' human cortical magnification factor?

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Scaling stimulus size by an estimate of the cortical magnification factor (CMF) is common practice in psychophysical experiments on peripheral vision. Yet what is the CMF's correct value? There is agreement that the inverse CMF increases mostly linearly with eccentricity in the visual field, so the question can be split into two parts: What is the CMF in the retinotopic centre? And what is the correct rate of decrease towards the visual periphery? After sixty years of research since the CMF's introduction, there is still surprising disagreement on these simple questions. Current fMRI estimates of the foveal CMF vary between 7.4 mm/° and 47.6 mm/°, i.e. by a factor of six. Similarly, current E2 values from fMRI for specifying the CMF's decrease towards the periphery range from 0.21° (i.e., steep decrease) to 3.67° (shallow decrease). This is even a factor of seventeen. Classical psychophysical estimates for grating stimuli fall well into those ranges, as do classical values for hyperacuity measures. The recently introduced d2 – denoting the distance from the retinotopic centre where the central CMF is halved – shows more stability but still varies between 6.93 mm and 18.8 mm, i.e. by a factor of three. The same holds for the comparably stable slope of the inverse-CMF vs eccentricity function. Differences in methodology cannot explain these differences. The "correct values" for the cortical magnification factor remain an open question.

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CNNs Reveal the Computational Implausibility of the Expertise Hypothesis

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Although considerable evidence supports the domain specificity of face processing mechanisms, not everyone is convinced. One alternative hypothesis holds that face mechanisms are engaged not only during face discrimination, but more generally during fine-grained discrimination of exemplars of any category for which one has gained substantial visual expertise (e.g., cars for car experts). Here we used deep convolutional neural networks (CNNs) to test the computational plausibility of this "expertise hypothesis". First, we performed experiments on CNNs optimized for either face discrimination or object categorization. We tested whether face-specific features or generic object features are more useful for a novel fine-grained car discrimination task by i) decoding car model/make classes from activation patterns of the penultimate layer of each CNN and ii) by retraining the fully-connected layers of each CNN for car discrimination. Both analyses found that the object-trained network outperformed the face-trained network ($p<0.01$, bootstrap test). Second, we used a dual-task CNN trained to discriminate both faces and objects, performing lesion experiments to ask whether retraining this network to a car task would recycle generic or face-specific features. We found that lesioning the top-20% face-specific filters in the network harmed the car performance less than lesioning the top-20% generic object filters. Moreover, the top-20% car filters recycled less face-specific than object filters. Our findings indicate that systems optimized more broadly for object recognition serve as a better basis than systems optimized for face recognition for subsequent acquisition of car discrimination expertise, thereby revealing the computational implausibility of the expertise hypothesis.

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Perceptual learning results in efficient re-allocation of sensory resources

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Although practice is known to improve perceptual performance, the computational principles underlying this improvement remain largely unclear. Here, we use psychophysics combined with mathematical modeling to probe the computational mechanisms of perceptual learning. Participants extensively practiced estimating the orientation of a peripherally presented grating. The orientation of the grating varied randomly across trials according to a Gaussian distribution, and participants performed the task at a single location in the visual field. Training occurred in daily 1-hour sessions across 10 days. Variability and biases in perception were measured before and after training, for both trained and untrained locations and all orientations (0-180°, in steps of 22.5°). We compared the human data to simulated data from 1) an observer model that adapts its prior beliefs with training (Bayesian), 2) a model that re-allocates its resources to maximize information about orientation (efficient coding), and 3) a model combining these two learning strategies. We found that the participants' orientation estimates improved markedly with training. While perceptual variability reduced for all orientations and locations, this reduction was reliably larger for trained orientations at the trained location. Interestingly, training also resulted in clear biases at the trained location, with perception being strongly repelled from orientations seen most often during training. This pattern of results was best captured by the efficient coding model. Altogether, these results suggest that perceptual learning leads to more efficient sensory representations, which maximize orientation information in a limited-capacity system.

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Bistable perception, precision modulation and active inference

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Bistable perception follows from observing a static, ambiguous stimulus with two possible interpretations. Here, we present an active (Bayesian) inference account of bistable perception and posit that perceptual transitions between different interpretations ensue from specific eye movements that shift the focus to a different visual feature. Formally, these inferences are a consequence of precision modulation that determines how confident beliefs are and change the frequency with which one can perceive (and alternate between) two distinct percepts. We hypothesised that there are multiple, but distinct, ways in which precision modulation can interact to give rise to bistable perception. For this, we hypothesised that high sensory precision would decrease the frequency of visual perception alternation. Additionally, increased state transition precision and/or increased policy selection precision would attenuate the

frequency of visual perception alternation. We validated our hypothesis using numerical simulations of the Necker's cube paradigm and demonstrate that multiple routes underwrite the frequency of perceptual alternation. We found that high sensory precision attenuates the influence of state transition precision and policy precision on the frequency of perceptual switches. These results provide a computational account of the intricate precision balance underwriting bistable perception.

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Poster session 30. Crowding

Use of Crowded Landolt-C charts can lead to reduced impact of crowding in strabismic amblyopia.

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Visual acuity is degraded by the presence of nearby optotypes due to masking and crowding. Crowding is more extensive in strabismic amblyopia, so to detect amblyopia, optotypes are placed close together on acuity tests. Crowded-C charts for near (Oculus, Wetzlar, Germany) place Cs 2.6 arcmin apart to maximise crowding. We examined the impact of fixed arcmin spacings on crowding magnitude (logMAR) as defined by "crowded" acuity (Cs with 2.6 arcmin spacing) minus "isolated" acuity (Cs with ≥35 arcmin spacing).

Research acuity data from the Child Vision Research Unit (Goethe University) were analysed from 30 anisometropic amblyopes (14, ≤8 years), 67 strabismic amblyopes (37, ≤8 years) and 76 healthy controls (36, ≤8 years).

Crowding magnitude (mean±1SE) depended on patient group [$F(2,170)=38$; $p=0.0000$]. It was higher [$p=0.00002$] in strabismic amblyopic (0.30±0.01 logMAR), than in anisometropic amblyopic (0.10±0.01 logMAR), control (0.09 ±0.01 logMAR) and fellow (0.12±0.02 logMAR) eyes. Strabismic amblyopes with "isolated" acuities <0.4 logMAR demonstrated stronger masking/crowding with worsening acuity (slope±1SD=0.53±0.33). Those with "isolated" acuities ≥0.4 logMAR, demonstrated weaker masking/crowding with worsening acuity (slope ±1SD=-0.18±0.07). Differences in slope were confirmed in children ≤8 years (<0.4 logMAR, slope±1SD=0.79 ±0.48; ≥0.4 logMAR, slope±1SD=-0.24±0.09).

Use of fixed (arcmin) spacings affects masking/crowding contributions at different acuity levels. Strabismic amblyopes unable to resolve 2.6 arcmin in "crowded" acuity measures may use new cues for gap localisation. Their "isolated" acuity measures (≥35 arcmin spacing) may also engage crowding. Both factors could result in reduced clinical measures of crowding magnitude.

Funding: URF (UoH) and ERA-NET Neuron (BMBF01EW1603B); Augenstern-e.V. (GU)

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(Un)crowding is pre-attentive

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In crowding, perception of a target deteriorates in the presence of nearby flankers. Crowding can be undone when additional flankers are presented, an effect known as uncrowding, which occurs when the flankers group with each other and ungroup from the target. A major question is whether this grouping process occurs automatically or requires attention. We investigated this question using a dual-task paradigm. Participants simultaneously performed a foveal discrimination task and a peripheral Vernier offset discrimination task. The foveal task was either feature-relevant with the crowding task (orientation or shape discrimination) or feature-irrelevant (color discrimination). In the peripheral task, participants reported the Vernier offset direction with the Vernier presented in isolation (baseline), surrounded by one square (crowding), or by seven squares (uncrowding). We found a main effect but no interaction, i.e., performance deteriorated in all three conditions (Vernier alone, crowding, uncrowding) because of the attentional load of the foveal task. However, the deterioration was roughly the same for the three conditions. We suggest that (un)crowding occurs with low attentional resources.

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The effect of eccentricity and target-flanker similarity on the spatial profile of crowding

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Visual crowding from nearby distractors (flankers) causes systematic errors in target identification that follow flanker appearance. This occurs within 'crowding zones' around targets which are larger with eccentricity, although the

effect of eccentricity on crowded perception within crowding zones is not well understood. We investigated how the combined influences of eccentricity and target-flanker similarity would affect the spatial extent of crowding zones and the pattern of crowded responses within them. Participants (n=3) reported the orientation of a target Landolt-C presented at each of three eccentricities (4.2°, 12.7°, 21.2°) and scaled for cortical magnification, in a continuous report task. Identical tangential flanking Landolt-Cs were presented at 5 levels of centre-to-centre separation and 3 orientation differences relative to the target. Distributions of errors were modelled as a mixed pair of von Mises distributions and relative contributions of target and flanker responses were calculated. Accurate target responses decreased as flankers approached the target under all conditions, following a logistic function. Inflection points, taken as a measure of crowding zone extent, were invariant across target-flanker orientation differences. At all eccentricities, the smallest target-flanker orientation difference produced shallow logistic functions, indicating a slow and widely dispersed increase in crowded errors with encroaching flankers, whereas larger orientation differences gave more abrupt step-like changes. The difference in the slope of these functions was greatest at the furthest eccentricity. We infer that target-flanker similarity modulates the profile of errors, without altering the extent of the crowding zone, and that this modulation is most prevalent at further eccentricity.

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Crowding results from optimal integration of visual targets with contextual information

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Crowding is the inability to identify and recognize objects in clutter, despite their being clearly visible, and recognizable when presented in isolation. Crowding is a major bottleneck to peripheral vision and as such it has always been considered a deleterious phenomenon. Given the abundance of contextual effects in vision we asked, on the other hand, if crowding wasn't complying with rules of optimal integration of target and flankers. To this aim we measured the bias and the variance in an orientation reproduction task of crowded ovals with different reliabilities. We found that: (I) crowding strength depends on target saliency; (II) flankers-induced bias is maximal when target and flankers have similar orientations; (III) flanker interference is associated with higher precision in judgements, that leads to lower overall error; (IV) effects are maximal when the orientation of the target is near that of the average of the flankers, rather than to that of individual flankers. These properties are in line with an ideal Bayesian observer which complements noisy information with that of the context. Overall, our results provide a framework for interpreting diverse findings in the crowding literature such as the effect of flanker-target similarity or the effect of flanker grouping.

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Assessing Peripheral Crowding Strength Using a Continuous Eye Movement Paradigm

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The inability to distinguish an object in the presence of clutter is referred to as crowding. Crowding imposes a fundamental constraint on human vision, limiting visual performance on a variety of tasks. Crowding is affected in various ophthalmic and neurological disorders. However, it is not routinely examined because currently, measuring crowding relies on classical psychophysical methods (button presses, complicated instructions) which take a long time and are attentionally demanding. If we would have a crowding assessment that would be faster, more intuitive and demanding less attention, this could open-up crowding for routine testing. Here, we describe an approach to measure crowding using continuous eye movements. The stimulus screen consists of clusters of Gabor patches (resembling "flowers") oriented in a hexagonal grid. Each flower consists of a central item (which can be a target or non-target), surrounded by six flankers. Half of the clusters contain a target and half of them contain non-targets. In the control condition, there are no flankers surrounding the central items. During a trial, the participant is asked to preferentially gaze at oriented targets (e.g. right tilted) among differently oriented non-targets (e.g. left tilted) as quickly and accurately as possible. Using this paradigm we were able to demonstrate the deleterious effect of flankers on target localization (evident from higher orientation discrimination thresholds). With this new paradigm we aim to

have a faster and more intuitive crowding assessment tool which shows prospects for use in clinical testing.

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Exploring the characteristics of foveal temporal crowding

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When a stream of stimuli is presented sequentially to the same location, it creates 'crowding' in the temporal domain, even when the stimuli are separated by long intervals. We recently showed that Temporal Crowding impairs encoding precision and increases substitution errors, and that this impairment has a similar magnitude at the periphery and the fovea. In this study, we explored key characteristics of this impairment.

Experiment 1 examined whether temporal crowding stems from forward interference or backward interference. Participants saw a stream of three circles, embedded in noise, each with a randomly oriented line. The stimuli were separated by an SOA of either 200ms or 400ms. The participants were instructed to report the orientation of one stimulus from the sequence: the first, second or third. Temporal crowding was largest for the second item, followed by the first, with hardly any impact on the third. This can only be accounted for by a combination of strong backward interference and weak forward interference.

In Experiment 2, the participants always had to report the orientation of the second stimulus. Critically, the distractors (the first and third circles) either included a line or not. Temporal crowding was considerably larger when the distractors included an oriented line, yet they had a detrimental effect even without it. This suggests that the interference brought about by temporal crowding does not merely reflect response competition.

Taken together, we describe this temporal limitation and suggest that visual representation is susceptible to interference for a longer time than previously reported.

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Poster session 31. Peripheral Vision

Foveal Feedback is Specific to the Parvocellular System but not to Shape Related Tasks

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According to the foveal feedback (FF) hypothesis, shape information presented in the visual periphery is processed by the foveal cortex (Williams et al., 2008). In their study, Fan et al. (2016) reported an impairment in performance when a foveal distractor was presented between 150-300 ms after target onset. However, it is unclear if this drop in performance can occur also for tasks that are not about shape. Using the same procedure as Fan et al. (2016) we tested if FF is specific to the parvocellular system. Participants had to report which one of two gabors had the higher contrast by pressing a key. The gabors were presented in diagonal quadrants on two sides of the central fixation point (7° of eccentricity). A mask was presented foveally at different SOAs (0, 50, 150, 250, 350 and 450 ms; a no-mask baseline condition was also present). Manipulating spatial and temporal frequency as well as contrast, we created two conditions in which the stimuli activated mainly the magno- or the parvo system. Results are in line with our hypothesis: the non-linearity of the best model for SOA showed the presence of a dip specific to the parvocellular condition. The magno condition was affected by the mask but performance was linearly related to SOA. Our results suggest that FF may occur not only for difficult shape discrimination tasks, but for most tasks as long as they engage the parvo system.

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The role of similarity and bias in letter acuity measurements: a noisy template model

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Previous studies have demonstrated that similarity and bias are major causes of errors in the identification of Sloan letters in visual acuity testing. However, these two factors and their relative contribution have not been investigated extensively at central and paracentral visual field locations.

Using the method of constant stimuli, psychometric functions and visual acuity were measured in 10 observers at central and paracentral ($\pm 3^{\circ}$ vertical meridian) visual field locations. A "noisy template" model was developed to distinguish biases and similarities from random errors in letter identification.

At all three test locations, we found that the best model was one that combined the effects of both bias and similarity. The relative contribution of bias was higher than similarity, especially in central vision. Additionally, biases may exclusively explain variations in letter identification performance for small letter sizes at the three test locations. For larger letter sizes, similarity between letters played some role in

identification performance in the periphery, while the contribution of bias was higher, especially in central vision. In clinical vision tests, most letter sizes are supra-threshold, and so it is plausible to attribute differences in identification performance, especially in peripheral vision, to similarity alone. However, it will be important to investigate this assumption and to examine whether bias and similarity are likely to have a clinically significant effect on measures of visual performance and letter acuity in the periphery.

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Reading abilities in Deaf: Role of Fovea and Parafovea

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At the visual level, reading involves the processing of fixated words in foveal vision. While attention to parafoveal information may facilitate foveal word recognition, too much attention to parafoveal region may in contrast hinder identification of the foveal word. There is evidence that deaf individuals present enhanced attention allocation to the periphery, relative to hearing individuals, in low-level visual perception tasks. However, studies examining the impact of this redistribution of attention on the deaf reading skills are still scarce. The present study therefore aims to explore how deaf and hearing adult readers identify letters and words in foveal and parafoveal regions. Word identification was measured by presenting displays of three three-letter words, one on fixation and the others to the left and right of the central word. Accuracy in identifying the component letters of these words when presented at the same location in a context of three three-letter nonword sequences was also measured. Preliminary results showed similar performance by both populations. In the word identification task, accuracy was highest for central targets, followed by words presented in the right hemifield. For letters, accuracy was greatest for the three central letters and for the external ones, i.e., first and last letter of the complete sequence. These results provide evidence for an extended W-shaped serial position function for letter-in-string identification across both populations. Implications of this serial position function, an important factor underlying skilled reading, are discussed with reference to perspectives on visual span in deaf readers.

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Contrast constancy in peripheral vision: an old problem with a new colour

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Previous studies suggest an interesting divergence between the visual system's response to contrast at threshold compared to suprathreshold levels. Despite a strong reduction of contrast sensitivity at, for example, high spatial frequencies or increasing eccentricities, suprathreshold perceived contrast is largely independent of these factors, remaining consistent across different spatial frequencies or eccentricities, demonstrating "contrast constancy". While it is established that human red-green colour vision has a more dramatic decline in sensitivity across eccentricity than achromatic vision, there have been relatively few measurements of suprathreshold contrast effects. Here, we use a suprathreshold contrast matching paradigm to measure how perceived contrast differs between the fovea and the periphery. We first measured observers' detection thresholds in foveal and peripheral visual field across different conditions: achromatic, L/M (isoluminant red-green), and S/(L+M) (blue-yellow), at spatial frequencies ranging from 0.5 to 8 cycles/deg. Next, observers were asked to match the peripheral test stimulus to a foveal reference contrast fixed at 1 of 5 predetermined levels, and the differences in perceived contrast between the fovea and periphery were compared to differences in detection threshold. Our results showed that, across achromatic and chromatic conditions, there is a lack of contrast constancy at low contrast levels, and only at higher contrast levels does the perceived contrast in the periphery approach foveal levels. This result is surprising as previous research in achromatic vision showed veridical matches of the peripheral stimulus to fovea over a wider range of contrasts.

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Coarse perceptual information about peripherally presented stimuli in the Foveal cortex. An fMRI study on the periphery-to-fovea feedback

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The overall consensus on the role of feedback connections in vision is that recurrent activity from higher visual areas of the ventral visual stream modulates bottom-up, retinotopic information in order to enhance task-relevant features or bias perceptual hypotheses toward internal

models and expectations. Although this interpretation seems to be consistent with neuroimaging and behavioural data, there is a growing body of evidence suggesting that something might be missing from the picture. For instance, it has been shown that task-relevant, non-retinotopic feedback information about peripherally presented stimuli can be decoded in the unstimulated Foveal cortex (i.,e., the small patch of retinotopic cortex in the occipital pole responsible for processing foveal information), and that the disruption of this feedback – through Transcranial Magnetic Stimulation or behavioural masking paradigms – has detrimental effects on subjects' performance in a same/different task with peripheral pairs of stimuli. In order to help understanding the role of the periphery-to-fovea feedback, here we applied Multi-Voxel Pattern Analysis (MVPA) techniques to fMRI data (n=24) to decode stimuli information in the foveal cortex for peripheral stimuli belonging to real-world categories (motorbikes, cars, female and male faces) that vary systematically over the perceptual and categorical dimensions. Our results suggest that the information fed-back to the foveal cortex might carry coarse, low-level perceptual information (vs. high-level, fine-grained categorical information).

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Poster session 32. Magnitude Time Numerosity

Cortical quantity representations of visual numerosity and timing overlap increasingly but remain distinct

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Various quantities, including numerical and temporal quantities, show behavioral interactions. A predominant theory ascribes such interactions to a generalized magnitude system with shared neural responses between the quantities. Recently, 7T fMRI and neural model-based analyses have revealed largely overlapping networks of cortical maps with a topographic progression of preferred quantities: both the numerosity of visual objects and the timing (duration and period) of visual events. Evidence that such quantity-selective responses are linked to perception of their respective quantity is accumulating. From posterior to anterior brain areas, the neural response preferences within both networks become more specific, more tightly linked to behavior, and more abstracted from sensory stimulus properties. As such, here we ask whether numerosity and event timing are being hierarchically transformed into a common representation that might underlie their behavioral interactions. We find that the cortical overlap between numerosity and timing maps increases in posterior-anterior and inferior-superior hierarchies. However, nowhere in these overlapping networks do we find consistent correlations between numerosity and timing preferences. Therefore, representations of these quantities are brought together in the same brain areas, without transforming them onto a common representation. This suggests that behavioral interactions result from interactions between distinct neural populations responding to different quantities.

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Scalable representations of numerical magnitude in human frontoparietal cortex

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The ability to process numerosity has been reported across a variety of animal species and has been considered advantageous for survival. In humans and non-human primates, numerical information is encoded with numerosity-tuned neural populations in the frontoparietal network. However, it is still unclear whether the activation patterns of such numerosity-tuned neural populations are fixed to specific numerical magnitudes or flexibly adjusted according to the context of observed numerical magnitudes (i.e., scalable coding). Here, using functional magnetic resonance imaging with multi-voxel pattern analyses, we show that numerosity representations are scaled depending on the range of numerical magnitudes involved in the context. We trained a classifier to discriminate the numerical magnitudes of visual dot arrays from multi-voxel activation patterns observed for three partially overlapping numerosity sets. Specifically, we tested whether the classifier trained to classify a set of numerosities could decode the numerical magnitudes of the other sets. We found that the classifier was able to classify the numerosities based on their relative position of the magnitudes, whereas it failed to discriminate their absolute magnitude presented in a different context. This indicates that numerosity representations are scaled according to the range of numerosity involved in the context. Such context-dependent optimization of numerosity representation was ubiquitous across the frontoparietal network. Scaling neural representation of numerosity suggests an efficient scheme to use limited neural resources, where they are assigned based on relative magnitudes of numerosities within a context rather than its absolute magnitudes.

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Groupitizing, as subitizing, modulates early visual component of the EEG signal

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Numerosity estimates are more precise when items are clustered into groups rather than randomly distributed. This phenomenon, termed "groupitizing", is thought to rely on the recruitment of the subitizing system (fast and errorless estimation for set size up to ~4). Recent results indicate that both subitizing and groupitizing require attentional resources and that also the number of groups can be subitized, suggesting shared mechanisms.

The current study investigates whether groupitizing drives specific electrophysiological responses, reflecting the involvement of the subitizing system. Event-related-potentials (ERPs) were recorded while participants were involved in a numerosity estimation task in the subitizing range (3-or-4 items) or in the estimation range (6-or-8 items). In this latter case, stimuli could be randomly scattered or arranged into few spatially segregated groups (3-or-4 groups).

Behavioural results indicate higher precision for numerosity estimation of grouped stimuli, compared to random arrays in line with the previous literature. The electrophysiological results show that for ungrouped arrays, the N1 component peaked earlier in response to the largest numerosity in both ranges (i.e latency for 4<3 and 8<6). Interestingly, in the grouped condition, N1 peaked earlier for set of stimuli containing more groups despite they entailed less elements (i.e. latency for N6 (4groups= 2,2,1,1) < N8 (3groups= 3,3,2)).

Overall, our results provide the first electrophysiological evidence of a link between groupitizing and subitizing. In particular they support the hypothesis that groupitizing leverages on the capacity to subitize the number of groups of elements similarly to the typical subitizing effect reported for single items.

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Magnitude integration of time and numerosity evaluated using Maximum Likelihood Estimation (MLE) model

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Time and numerosity are constituted in different dimensions, but their magnitudes interact with each other. For example, the stimulus with larger numerosity is perceived to last longer than that with smaller numerosity. While such interactions have been widely reported, their mechanisms remain unclear. The maximum likelihood estimation (MLE) is one way to model the interaction. Studies on cue integration reported that human observers integrate multiple sources of information in a statistically optimal fashion in the sense that the integrated estimate is most reliable. Here we hypothesized that the perceptual system has a function to achieve the most reliable magnitude estimate of the stimulus by integrating time and numerosity information via MLE, resulting in the interactions between them. We tested this hypothesis by presenting the time and numerosity information within the same visual stimulus. Participants compared the magnitude of two stimuli based on either time or numerosity alone or both. The results showed that the integration of time and numerosity is qualitatively consistent with the MLE predictions. However, quantitatively, the observed weights and precisions systematically deviated from the predictions; the numerosity weights were larger, and the precisions of the integrated estimates were lower than predicted. These results suggest a compensatory mechanism similar to the reliability-based weighting, which could underlie interactions between time and numerosity. We will discuss possible reasons for the discrepancies between the observed and the predicted data. We will further interpret the findings in the context of A Theory Of Magnitude (ATOM).

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Numerosity processing in the dyscalculic brain

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Developmental dyscalculia is a neurodevelopmental disorder which affects the acquisition of basic arithmetic skills. The aim of our study was to understand the discrepancies in cortical processing of numerosity, especially in the parietal cortex, between neurotypical adult controls (N=10) and dyscalculic adults (N=10) using fMRI. Scanning was performed with a GE 3T scanner (Excite HDx, GE Medical Systems, Milwaukee, WI). We presented clouds of non-overlapping dots (0.3° diameter), half black half white, which varied along two orthogonal axes: area and density, with numerosity (9, 16, 25) lying on one diagonal. We used a dynamic adaptation procedure, with each stimulus presentation consisting of four different configurations of the same condition presented sequentially (250 ms each) followed by a blank of 6.5, 9 or 11.5 seconds. For the entire

scan, participants were required to keep fixation on a central red dot. We observed strong activation throughout the occipital, parietal and temporal lobes of both participant groups. In typical adults, BOLD adaptation was stronger along the numerosity vs the non-numerosity axis in parietal areas associated with the number sense (Castaldi et al., 2016). In those specific areas in dyscalculic adults, we found no evidence of adaptation, despite the stimulus response being present and strong, but we did observe stronger adaptation in temporal areas typically processing other stimulus characteristics, such as form and motion. We reason those areas outside the dyscalculic parietal cortex attempt to retrieve as much information possible to make up for the inability to process effectively numerosity information.

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Poster session 33. Visual Search & Foraging

Friend or Foe: The Role of Semantically Related Distractors during Bilingual Object Search

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Bilinguals activate knowledge from both known languages when interacting with their environment (i.e., non-selective activation). Evidence of this comes from both first and second language reading, when working memory is burdened with resolving two conflicting representations resulting from words sharing form but not meaning (interlingual homographs; e.g., CRANE - skull in French, machine in English). The aims of this study were to investigate whether effects of non-selective activation extend to visual object search and to determine how the presence of semantically related objects modulates these effects. Fifty-eight French-English bilinguals performed a visual search task, while their eye movements were recorded. They decided whether a circular search array contained an object that corresponded to a visually presented word cue. Word cues were interlingual homographs or language-unique words. The images in the search arrays contained the representation of the cue, the interlingual homographs' meaning in the non-target language and, in some trials, an additional semantically related object. Participants completed the task in English and French. For interlingual homographs vs. language-unique words, response accuracy was lower and reaction times were longer. Verification times were longest for homographs when no semantically related object was presented, but there was no difference in the number of objects fixated during searches. This suggests that while there is evidence of interlingual homograph interference during object search, the additional attentional distraction introduced by the presence of a semantically related object did not obstruct search, but instead might constitute semantic context that boosted participants' target template and thus search performance.

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Perceptually non-distinctive uniqueness in eye of origin of visual inputs boosts saliency by unique color and/or orientation: implications for mechanisms in the primary visual cortex

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Among homogeneous non-targets, the reaction time (RT) for finding a target unique in orientation (O) is shortened when this target is also unique in color (C). RT(CO) for finding this double-feature target CO, unique in both C and O, is shorter than predicted by a statistical facilitation (Raab 1962) between RT(C) and RT(O) for the single-feature targets C and O (Krummenacher et al 2001, Koene & Zhaoping 2007), implicating contributions by neurons conjunctively tuned to C and O. The RT for a target unique in O is also shortened by making the target also unique in eye of origin (E), e.g., the target/non-targets shown to the left/right eye, implicating the primary visual cortex (V1, Zhaoping 2008). However, the RT(E) for a target unique only in E is unmeasurable directly, since E is perceptually non-distinctive (Wolfe & Franzel 1988).

Confirming and extending the previous findings, we show that the RT for a target C, O, or CO becomes shorter by making the target unique in E additionally. Furthermore, using the V1 saliency hypothesis, we derive RT(E) (if E singletons were perceptually distinctive for our task) from the measurable RTs for targets unique in C, O, CO, CE, EO, and CEO.Additionally, we infer the contribution by V1 neurons conjunctively tuned to both of the unique target features, e.g., C and E, to saliency by examining whether, e.g., RT(CE) is shorter than predicted by the statistical facilitation. The significance of this contribution depends on the colors of both the target and non-targets.

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Which search are you on? Adapting to shape while searching for color

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It is known that humans adjust their attentional control settings when searching for targets in sophisticated

environments. Systematic dynamic changes in features that help discriminate targets from distractors can be utilized to guide search. It is less clear whether observers also adapt to dynamic changes in distractor features which are not necessarily relevant to find the targets. Some evidence in favor for such adaptation has been found for color as a non-target dimension. In two experiments we examined whether observers also adapt to systematic changes in distractor shapes while searching for color singleton targets. The task could be completed by taking the color dimension into account alone and participants could freely choose between two color targets that shared some shape features with the distractors. Results showed that participants adjusted their target selection to the ratio of the two shape distractor types. They preferred to choose the target from the smaller shape subset, and the time course of this adaptation showed that the regularity of the change was taken into account as well. We conclude that observers adjust their behavior to changes in the environment even when the changes are not task-relevant. Our Bayesian modeling method assessed the extent and the delay of the adaptation, showing that it was similar to adaptation seen with color as distractor dimension.

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The effects of interruption on a subsequent visual search in the same environment.

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Sometimes, while searching for a target in the environment —such as a pen on a cluttered desk—, we might become disrupted, and the search cannot be completed, for example, if we are distracted by a phone call. In the present study, we examined how search behavior was affected by an interruption of the preceding search in the same environment. To this end, we conducted an eye-tracking experiment in which 25 participants searched the same display of 20 items (10 pink letters and 10 blue letters) twice consecutively, each time to find one target letter. The target was randomly embedded among the pink or the blue letters, but it was present only 50% of the time. In half of the trials, the first search was interrupted by the announcement of the second target via loudspeaker. We found that manual responses in the second search were significantly slower following the interruption of the first search in comparison to responses in the second search when the first search was completed. Furthermore, following an interruption, during the second search participants were more prone to fixate on items that shared the same color as the last fixated items in the first search. Collectively, these findings suggest that search efficiency in the same display diminishes when there is an interruption in the preceding search and that this interruption hampers the cognitive processes required to adjust to a new target.

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Guidance of visual search through canonical materials while controlling for low-level features

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Wolfe and Myers (2010) reported that materials do not efficiently guide visual search. However, the stimuli surface appearance varied largely for each material category. For example, the appearances of metal may vary from shiny to matte.

In a recent study, Zhang and Heinke (2021) aimed to control for this confounding factor by using canonical materials as stimuli (Zhang et al., 2020). They found efficient search for "specular" among "matte" and inefficient search for "matte" among "specular". But their findings could have been caused by the differences in low level features (e.g., lightness) between the two materials.

To control for low-level features, we created a new set of "matte" stimuli by superimposing the rotated highlights obtained from corresponding "specular" images. In this way, the new "matte" stimuli have the same bright pixels. However, due to the rotation, these bright pixels do not aligned with matte surface's shading. Hence they may not be perceived as specular highlights.

The resulting search task turned out to be very hard. The averaged accuracies were just above chance level. After removing participants who performed below chance, we found inefficient searches for both materials. The search slopes were above 35ms/item for the target present and above 50ms/item for the target absent condition.

Even though these results do not support Zhang and Heinke's previous findings,

the current study presents a rigorous approach to test human's ability to search for materials by systematically varying the appearance of canonical material modes.

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Pop-in: the inversion of pop-out during visual search in monkey brain area V4

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During visual search, it is important to reduce the interference of distracting objects in the scene. The neuronal responses elicited by the search target stimulus are typically enhanced. However, it is equally important to suppress the representations of distracting stimuli, especially if they are salient and capture attention. We trained monkeys to make an eye movement to a unique "pop-out" shape among an array of distracting stimuli. One of these distractor stimuli had a salient color that varied across trials and differed from the color of the other stimuli, causing it to also pop-out. The monkeys were able to select the pop-out shape target with high accuracy and actively avoided the pop-out color distractor. This behavioral pattern was reflected in the activity of neurons in area V4 where responses to the shape target were enhanced, whereas the activity evoked by the pop-out color distractor quickly became suppressed, after a brief phase of response enhancement. These results provide new insight into the cortical selection mechanisms that apparently can invert pop-out to 'pop-in' for an entire feature dimension to facilitate goal-directed visual search.

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The effects of auditory and visual synchrony on foraging

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Can synchrony in stimulation aid perceptual performance? A neon-sign with letters appearing asynchronously will confuse us, while letters appearing in synchrony are easily read. Secondly, can cross-modal synchrony aid performance? Here we tested the influence of visual and auditory synchrony on visual foraging. Experiments 1A and 1B were online experiments where the task was to forage for 10 (out of 20) vertical lines among 60 randomly oriented distractor lines that changed color at random intervals. In Experiment 1A targets either changed colors in visual synchrony or not, while in experiment 1B a non-spatial sound additionally occurred synchronously with the color change of the target. Experiment 2 was run in the laboratory (within subject) with the same design. When targets changed color in visual synchrony, foraging times were significantly shorter than when they randomly changed colors, but there was no additional benefit for sound synchrony. In experiment 3 task difficulty was increased as participants foraged for as many 45° rotated lines as possible among lines of different orientations within 10 seconds, with the same synchrony conditions as in experiments 1 and 2. Again, there was a large benefit of visual synchrony but no additional benefit of sound synchronisation. Our results provide strong evidence that visual synchronization aids foraging for multiple targets, perhaps reflecting facilitated grouping of synchronized targets. In contrast with predictions from previous visual search findings (e.g. the 'pip-and-pop' effect), there was little evidence for any additional benefit from sound synchrony.

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Co-activation of multiple attentional templates in colour versus shape search

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During visual search, attentional selection is guided by attentional templates – target representations held in visual working memory (WM). While some accounts suggest that only a single template is active at any time, others have observed that multiple attentional templates can be activated simultaneously to guide attention in parallel. However, most of these studies have used colour-defined search templates and it is unclear whether template co-activation can also be found for feature dimensions which have been suggested to have lesser guiding qualities, such as shape. To answer this question, we measured the N2pc component of the event-related potential under low and high WM load conditions in colour versus shape search. In different tasks, participants searched for a colour- or shape-defined target among four differently coloured shapes presented in circular search arrays. Search arrays were preceded by cue displays indicating the upcoming target colours (one or two coloured bars) or shapes (one or two grey shapes), respectively. N2pc components measured in the colour task mirrored previous findings: N2pcs were slightly delayed in the two than one colour search, reflecting mutual inhibition of two simultaneously activated colour templates. In the shape task, N2pcs were delayed overall, but critically, the relative latency costs caused by the increased WM load – in the two versus one shape search – were comparable to those measured in the colour task. These findings suggest that even though shape templates have less efficient guiding qualities than colour templates, they can still be co-activated if multiple shapes are task-relevant.

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