[EUROPEAN CONFERENCE ON VISUAL PERCEPTION (ECVP)]

27-31 AUGUST, 2023
PAPHOS - CYPRUS

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Spatial Cognition and Artificial Intelligence: Methods for In-The-Wild Behavioural Research in Visual Perception

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ABOUT

The tutorial on "Spatial Cognition and Artificial Intelligence" addresses the confluence of empirically-based behavioural research in the cognitive and psychological sciences with computationally-driven analytical methods rooted in artificial intelligence and machine learning. This confluence is addressed in the backdrop of human behavioural research concerned with naturalistic, in-the-wild, embodied multimodal interaction. The tutorial presents:

(1) an interdisciplinary perspective on conducting evidence-based human behaviour research from the viewpoints of visual perception, environmental psychology, and spatial cognition.

(2) AI methods for the semantic interpretation of embodied multimodal interactions (e.g., rooted in behavioural data), and the (empirically-driven) synthesis of interactive embodied cognitive experiences in real-world settings relevant to both everyday life as well to professional creative-technical spatial thinking

(3) the relevance and impact of research in cognitive human-factors in spatial cognition for the design and implementation of human-centred AI technologies

The main technical focus of the tutorial is to provide a high-level demonstration of general AI-based computational methods and tools that can be used for multimodal human behavioural studies. Of special focus are visuospatial, visuo-locomotive, and visuo-auditory cognitive experiences in the context of application areas such as architecture and built environment design, narrative media design, product design, cognitive media studies, and autonomous cognitive systems (e.g., robotics, autonomous vehicles). Presented methods are rooted in foundational research in artificial intelligence, spatial cognition and computation, spatial informatics, human-computer interaction, and design science.

The tutorial utilises case-studies to demonstrate the application of the foundational practical methods and tools. This will also involve practical examples from large-scale experiments in domains such as evidence-based architecture design, communication and media studies, and cognitive film studies.

SCOPE AND AUDIENCE

>> SCOPE. Interdisciplinary scientific agenda targeting an audience with an interest or curiosity in visual and spatial cognition, visual perception, and artificial intelligence (emphasis on knowledge representation and reasoning, and high-level event perception). Particular focus will be utilising case-studies to demonstrate the state of the art in artificial intelligence, cognitive vision, and applied perception with respect to their impact on eye-tracking in particular, and multi-modal human behavioural research in general.

>> AUDIENCE. (1) Interdisciplinary audience interested to learn about how research in Cognition, AI, Interaction, and Design comes together; (2) Young researchers (e.g., masters and early stage doctoral candidates) desirous of exploring open research questions and avenues for visual perception research, and how it could influence the design of AI technologies; (3) Learn about applications of spatial cognition research in application domains such as (building) architecture design, (visuo-auditory) narrative media design, human-robot interaction, autonomous vehicles; (4) Design practitioners from areas such as architecture, animation, visual art, digital media, interaction design seeking to get insights from existing case-studies involving eye-tracking based visual perception in their respective domains of application; (5) Research generally curious to lean about what AI methods have to offer to behavioural research in cognitive science and psychology.

Understanding Glare's transformation of scene luminance into the different pattern on the retinal receptors

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This course connects the measurements of physics with those of psychophysics (visual appearance). Our visual system performs complex-spatial transformations of scene-luminance patterns using two independent spatial mechanisms: optical and neural. First, optical glare transforms scene luminances into a different light pattern on receptors, called here retinal luminances. This tutorial introduces a new Python program that calculates retinal luminances from scene luminances. Equal scene luminances become unequal on the retina. Uniform scene segments become nonuniform retinal gradients; darker regions

acquire substantial scattered light; and the retinal range-of-light changes substantially.

High-Dynamic-Range(HDR) Imaging is the most dramatic example. Human optics cannot transmit the full range of a million:1 transparency test targets to their retinal images. One such HDR target contained 40 Gray squares segments placed on a max-luminance surround subtending 16°x19° The squares' luminance range was [250,000:1]; retinal luminance range[33;1]. A second HDR target with these 40 Gray squares on a min-luminance surround had luminance range [250,000:1]; retinal luminance range [5000:1]. Observers reported that whites (with equal luminances) appeared the same white in both experiments. Remarkably, blacks appeared the same black in both experiments despite the change in retinal luminances range from 33:1 to 5000:1. There is no single Response Function (Luminance-in vs. Appearance-out) that fits all complex HDR scenes.

Our new Python (open-platform) program calculates glare on each pixel (representing a receptor) as the sum of the individual contributions from every other scene segment. Glare responds to the content of the entire scene. Glare is a scene-dependent optical transformation.

Quantitative measurements, and pseudocolor renderings are needed to appreciate the magnitude, and spatial patterns of glare. Glare's gradients are nearly invisible, or invisible when you inspect them.

Neural processing performs vision's second scene-dependent spatial transformation. Neural processing generates appearances that do not correlate with the quanta catch of receptors, such as Simultaneous Contrast, and Assimilation Illusions. As well, Edwin Land's Black and White Mondrian, and Ted Adelson's Checkershadow make the same argument for visual appearance's dependence on the spatial content of complex scenes. Illusions are generated by neural processing of the "rest-of-the-scene". The neural network input is the simultaneous array of all receptors' responses after glare.

Recent glare studies of Lightness illusions used scene luminances of only 200:1 The absolute amounts of glare are much smaller. However, the principles are the same. White scene segments have only very subtle modifications of uniformity near boundaries; Gray segments have larger changes in uniformity and average value; Black segments have considerable disruptions of uniformities and substantial variability of average values. Both Contrast and Assimilation have two unusual properties. First, they both restrict the "rest-of-the-scene" to only Whites and Blacks segments. Whites are glare's maximum donor; Blacks are most affected by glare. The second property is relative angular size, angular separation of donor and receiving pixel, and enclosure. Contrast has larger Grays and larger surrounds. That separates Contrast's donor and most-affected receiving pixels, and places individual pixels at lower intensities on the Glare Spread Function. Michael White's Assimilation has long-narrow Grays with long-narrow surrounds. That brings Assimilation donor and most-affected receiving pixels closer together , and places individual pixels at higher intensities on the Glare Spread Function. Both of these properties accentuate the effects of glare.

In summary, the tutorial describes how optical glare affects imaging in human vision, cameras and displays. As vision's first spatial imaging transformation it modifies the pattern of scene luminances, and makes a different pattern of light on retinal receptors. The complete array of all receptors is the simultaneous input to the second spatial transformation, neural image processing. The tutorial does not discuss theoretical mechanisms and neural models, it pays attention to observations of appearances of scene segment. Vos and van den Berg's 1999 CIE Glare Spread function is the basis of understanding Glare. The tutorial describes our new Python code that calculate the pattern of light on receptors. These scene transformation are a morass of gradients that are hard to see. The tutorial explains the need for numerical analysis (histograms and plots of calculated retinal luminance) as well as Pseudocolor renditions to visualize retinal patterns.

The tutorial explains glare's role in vision, and in technology covering many topics including HDR, LDR illusions, visibility of gradients, Pseudocolor pattern visualizations, and other topics related to glare's spatial transformations of scene luminances, and their appearances.

Modelling the spatio-temporal properties of eye movements: methods, devices and applications

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This tutorial aims to provide a comprehensive overview of SONDA (Standardized Oculomotor Neuro-ophthalmic Disorders Assessment), a powerful yet simple method for analyzing the spatio-temporal properties of eye movements with relevant applications in fundamental and clinical vision research. By integrating insights from experimental research in visual neuroscience, psychophysics, and machine learning, this tutorial will offer participants a unique opportunity to understand better how the SONDA method can be used to study eye movements and their practical application in different clinical contexts. A novel medical device based on this method will be demonstrated during the tutorial.

The expected learning outcomes of this tutorial include:

Understanding the basic principles of the SONDA method: continuous psychophysics, eye-tracking signal processing, fundamentals of neuro-ophthalmology.

Familiarization with the different components of the SONDA method, including stimuli design, spatio-temporal analysis based on cross-correlograms, saccadic perimetry, and saccadic dynamic properties.

Gaining insights into the strengths and limitations of the SONDA method and how to choose the appropriate analysis techniques for a given research question.

Understanding how to interpret and communicate the results of SONDA analyses to other researchers, clinicians, and the broader scientific community.

This tutorial is targeted towards researchers and students with a background in visual neuroscience, psychophysics, neurology, optometry, or ophthalmology who are interested in learning more functional vision assessment through eye movement data. Participants should have a basic understanding of statistical methods and programming skills.

The importance of this tutorial lies in the increasing relevance and availability of eye-tracking tools. Eye movements provide a valuable source of information about how the visual system processes information and generates behavior that can be used to investigate a wide range of research questions, from basic visual neuroscience to clinical applications. The SONDA method offers a powerful framework for analyzing eye movement data by integrating multiple types of analyses into a single experimental pipeline and providing a unified approach for investigating different aspects of visual perception in a simple and fast manner.

By providing a comprehensive overview of the SONDA method, compatible experimental setups and applications, this tutorial will enable participants to stay at the forefront of eye movement research in visual perception and contribute to developing new knowledge and applications in this area. Participants will be able to work with real eye movement data from different clinical populations and develop practical skills in applying the SONDA method to their research questions.

Visual psychophysics with OpenSesame

Sebastian Mathôt[1]

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Presenter: Sebastiaan Mathôt

In this ECVP tutorial, you will learn how to build a visual-psychophysics experiment in OpenSesame 4.0. You will learn how to display complex visual stimuli (Gabor patches, noise textures, etc.) and how to use a Quest adaptive procedure to maintain equal performance between participants and conditions. You will also learn how to verify the temporal precision of your experiment. The tutorial will focus on the graphical user interface, but there will additional challenges for those of you with Python coding experience.

Please bring your own laptop and install the latest version of OpenSesame 4.0 (not 3.3).

For more information, visit https://osdoc.cogsci.nl/4.0/ecvp2023

Dynamic vision and its development: a symposium in honour of Oliver Braddick.

Janette Atkinson[1]

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Our joint achievements and challenges in understanding visual development are in three inter-related areas of research. The first is infant visual brain development, where we used 'forced-choice preferential looking' (developed initially by Davida Teller) together with EEG 'frequency-tagging' steady-state VEPs to study the time course of visual cortical functioning in the first year of life. The model sets the timescale for functional development of discrimination of orientation, motion, binocular disparity and attention switching, with differential development in dorsal and ventral streams for motion and form coherence sensitivity and recurrent feedback circuitry in extrastriate visual processing.

Secondly, we invented isotropic photo and video-refractors to measure accommodation and refraction in infants and children of any age. We identified significant astigmatism in the first year of life in many typically developing infants, which usually autocorrected within 3 years. In screening programmes of 8000 infants, aged 9 months, we found that early correction of refractive errors reduced the incidence of strabismus and amblyopia.

The third area was in designing tests to detect visual impairment in infants and children with developmental disorders (Williams syndrome, Autism, Developmental Coordination Disorder, ADHD, cerebral palsy, very preterm birth). A common pattern emerged across many disorders which we called 'Dorsal Stream Vulnerability': a cluster of difficulties across coherent motion sensitivity, visuo-motor actions, visual attention and mathematics, related to development of the dorsal stream and integration between processing in dorsal and ventral streams. Ol's contribution to all these areas combined his ability to pinpoint important unanswered questions, skill in devising workable, reliable techniques, a clear theoretical perspective, humility and a fine sense of humour.

Development and plasticity of motion circuitry in human infants

Maria Concetta Morrone[1]

[1]Pisa university, Italy

Ol Braddick, with Jan Atkinson, were among the first to study extensively the development of the human motion system during the first few months of life, using both psychophysics and EEG. We measured fMRI BOLD responses to flow motion

stimuli in young, attentively collaborating infants, and showed that two major cortical areas subserving adult motion processing (MT+ and PVICS) are operative very early, by 5 weeks of age. Other dorsal motion areas, including V6 and pre-cuneus develop more slowly, around 8 weeks. V1 is not selective to flow motion, but its response to contrast also matures rapidly between 5 and 8 weeks of age. Restingstate correlations in 5-8 week-old infants show adult-like functional connectivity between the motion-selective associative areas, but not between primary cortex and temporo-occipital and posterior-insular cortices. Taken together, the results suggest that the early maturation of infant MT+ may reflect the rapid development of the peripheral visual system, dominated by M-cells, while the comparatively slower maturation of V1 may be limited by the dominant foveal representation, primarily Pcells.

This conclusion is supported by work with infants with periventricular leukomalacia, who show a strong correlation between extent of motion deficit and cortical thickness of area V1, but not area MT+. The results are in line with the idea that more than one motion system limits psychophysically measured thresholds, broadly consistent with Braddick's seminal notion of two motion systems.

Dynamic vision and its development: spatial coding and seeing in depth

Marko Nardini[1]

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Oliver Braddick's seminal work on vision and its development is part of a broader framework for understanding the organisation of behaviour and its development: "In considering visual development … we do not attempt to isolate classically 'perceptual' processes, but consider 'perception', 'cognition' and action' as aspects of an integrated behavioural and neural system.". I will describe research leading on from our collaborations and inspired to understand visual development in the dynamic context of the whole organism as it moves and acts in the world. I will discuss studies showing the developmental changes in spatial coding that underlie new capabilities for perception and action in early childhood. Our initial findings from environments carefully crafted in the lab are extended by newer work using VR methods which provide new kinds of control over visual and other sensory cues. I will also discuss research on the development of perception of 3D layouts via stereo and other cues. Efficient interactions between different depth cues show a surprisingly long developmental trajectory, in behaviour and in representations in early visual areas as assessed using fMRI/MVPA. Miscalibration of depth estimates via stereo vs other cues while the system is developing may be one factor limiting these interactions in childhood. Finally, I will outline ongoing research about interactions between vision and other senses to perceive spatial layouts. This includes investigations of the scope to augment perception of space, which has applications to people with vision loss and those carrying out tasks in unusual environments.

Two motion systems in the primate brain.

Anthony Movshon[1]

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Work by Braddick and others has psychophysically defined two processes that analyze directional motion. The "short-range" process is limited in both spatial and temporal integration, and has much in common with what is sometimes called the "first-order" motion system, based on motion detectors that are well described as linear filters. The "long-range" process can integrate over much larger spatiotemporal extents, and has much in common with the nonlinear "second-order" motion system.

Analysis of the responses of motion sensitive neurons in monkeys shows that neurons in V1, MT/V5, and other dorsal stream areas show the hallmarks of the short-range system: spatiotemporal filters that seem linear and are of limited span.

The brain location of the long-range system is less clear, but it seems not to be within the classical cortical motion pathways. Neurons in the ventral visual stream, in areas like V4, may be the substrate for the long-range process.

Multi-primary high dynamic range displays for vision science: implementation, challenges, and psychophysics

Allie Hexley[1]

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Much of our ability to understand the functionality of the visual system and non-visual light mediated responses in humans relies on our ability to manipulate light experimentally.

Progress is therefore limited by the performance of the equipment used to run psychophysical experiments. One classic example of this is the inability to study the role of photoreceptors beyond the cones with traditional three-primary display systems. To address this limitation, we demonstrated a novel multi-primary high dynamic range display, the RealVision MPHDR display, that is suitable for photoreceptor isolating vision experiments via the method of silent substitution.

The RealVision MPHDR display system is the first system, to our knowledge, that allows the delivery of spatially controllable, high-dynamic range, multiple primary stimuli. The development of such displays presents a challenge for quantification and comparison of display performance as traditional colorimetry methods are based on cone responses alone and fail to capture the full range of functionality of multi-primary displays. We have therefore also developed possible frameworks for considering the display gamut with reference to signals from all five photoreceptor classes. Finally, we present data from some proof-of-principle psychophysical experiments that demonstrate the utility of the display. Specifically, we show how the RealVision MPHDR is able to fill a niche in the current literature on melanopsin inputs to pupil size and investigate the melanopsin mediated pupil response over a large range of luminance levels that is more representative of the wide range of environmental light intensities.

Filling-in of the foveal rod scotoma under mesopic viewing conditions

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Depending on the illumination, two types of photoreceptors in the retina contribute to vision: Cones are active in photopic vision at bright illumination, whereas rods are active in scotopic vision at low illumination. At intermediate light levels in mesopic vision, both rods and cones are active simultaneously. Due to the absence of rods from the fovea at the center of the visual field, a foveal scotoma occurs in scotopic vision. It has been shown that this scotoma can be filled-in with information from the immediate surround. However, it is unknown whether such filling-in also occurs in mesopic vision when cones are active in the fovea.

We investigated filling-in of the rod scotoma in mesopic vision. We used a customized projector with four independent color channels to independently stimulate rods and three cones types. With cones silenced and only rods stimulated, our stimuli consisted of two concentric circles of 2D sine wave gratings. The size of the center was smaller than the rod scotoma, allowing information from the surround to fill-in the fovea. The orientation of the center and the surround was parallel or orthogonal. Participants had to indicate the orientation of the center.

Participants were unable to accurately discriminate the orientation of the grating in the center. Instead, the reported orientation of the center was biased towards that of the surround. This indicates that the missing rod information in the fovea is filled-in with information from the immediate surround even in mesopic vision when cones provide information at the fovea.

The contribution of rods and cones to brightness induction

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Retinal mechanisms are involved in the early processing of brightness. However, brightness induction studies that discriminate the contributions of rods and cones at the same light adaptation have been rarely conducted, possibly due to technical limitations. In this study, we assessed isolated rod, isolated cone, and combined rod and cone (LMSR) conditions for contrast and assimilation induction stimuli, using a four-primary projector and the silent substitution method.

We generated induction stimuli in mesopic light adaptation with embedded matching and reference patches. Participants had to choose the brighter patch and the induction effect was computed as the normalized difference between the patches' intensities at the point of subjective equality.

For the LMSR condition, contrast and assimilation induction stimuli produced similar responses, and these were significantly higher than responses for a control non-induction stimulus. Similar results were found for the cone condition, although there was a trend for a higher contrast than assimilation effect. For the rod condition, the brightness assimilation effect was significantly higher than brightness contrast. Comparing the three photoreceptor conditions, it became clear that the combined response under mesopic viewing was mostly determined by cones. Therefore, roddriven brightness induction is notably different from induction obtained in usual photopic or mesopic viewing conditions where cones are involved. We argue that the different behaviour for isolated responses could be explained by asymmetric retinal contrast gain for rods and cones.

How does melanopsin help us to see?

Tom Woelders[1]

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Besides rods and three cone types, the human retina expresses a third class of photopigment known as melanopsin, expressed in intrinsically photosensitive retinal ganglion cells (ipRGCs). IpRGCs were discovered in attempts to understand how endogenous circadian clocks are reset to the light:dark cycle and are still often considered 'non-visual' photoreceptors.

However, there is now abundant evidence that melanopsin photoreceptors also make an important contribution to the processes of perceptual vision. I will discuss work in which we have employed a multi-primary display to gain control of melanopsin activity, independent of chromaticity and luminance. We have used this approach to increase our understanding of

the potential contribution of melanopsin to colour vision, and to show that melanopsin modulates an optical illusion known as Troxler fading. I will discuss how this latter finding fits into the currently accepted framework where melanopsin is thought to complement the high spatiotemporal frequency tuning of the classical rod/cone system.

Melanopsin in complex scenes: Brightness and color interactions

Tanner DeLawyer[1]

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Utilizing a multi-primary display composed of three projectors with filters, we are able to create complex scenes that allow the manipulation of melanopsin stimulation levels in individual stimuli embedded into complex surrounds of varying luminance and chromaticity. This allows us to judge melanopsin dependent retinal ganglion cell contributions to brightness or color perception in comparison to the more established roles of cone stimulation in complex scenes where surround induction effects can influence color perception. Under conditions where the luminance and chromaticity of two simultaneously presented parallel stimuli are identical, melanopsin can have a relatively large contribution to brightness perception in a 2 alternative forced choice task.

However, as luminance and chromaticity in one stimulus change, the contribution of melanopsin to brightness judgements is greatly reduced. Additionally when surrounds are utilized that vary in melanopsin content this can have a significant influence (an induction of greenishness) on the perceived red/green balance point of centrally presented yellow stimuli. Currently our research is focused on the influence of luminance and chromaticity variation in surrounds along with melanopsin on red/green balanced targets, which can include gray and blue, in addition to yellow.

The relative contributions of each factor as well as interactions between these factors (luminance,

chromaticity, and melanopsin) are being evaluated to better understand their role in induction effects and potentially more complex phenomena such as color constancy.

Confirmation of required specifications for cognitive function tests based on eye-movement-measuring devices

Mitsunobu Kunimi[1]

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The number of fixations and gazing distances extracted from eye movements during visual attention tasks can be used to objectively evaluate cognitive function. In this study, the required specifications for a cognitive function evaluation paradigm (eye-tracking-based assessment of cognitive function; ETAC), which it was assumed would be applied to clinical situations, were examined.

As an ETAC task, we created a new visual task, which requires eye movements on a clock-like board in response to instructions presented in the center of the screen. This task requires attention switching and maintenance, task switching, and working memory (for task switching and following the instructions presented in the center of the screen while maintaining the current gaze location). In this study, eye movements during the ETAC task were measured, and the number of gaze retention points, the distance traveled by the line of sight, and the pupillary light reflex were used as physiological indices, and the reaction time and number of correct responses were used as behavioral indices.

According to the results of this preliminary study, (1) switching tasks results in a cognitive load being applied, and "wandering" of the line of sight is observed; (2) the current gaze position is confirmed after the instructions are presented; and (3) fatigue increases the delay of the task performance speed and the movement of the line of sight to the outside of the target. These results reflect the function of the central executive system, working memory (retention), and attention.

This work was supported by JSPS KAKENHI Grant Number 20K03396.

Fixational Eye Movements As Bio-Markers For Visual Acuity

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Visual acuity is one of the most fundamental measures that interest both patients and eye-care professionals, as it expresses the crucial capacity of our visual system for differentiating spatial details. For years, and till this day, the Snellen chart test (and its variants) represents the gold standard for estimating visual acuity. However, this test is not perfect and several of its limitations call for alternatives. In this context, here we explore the correlation between fixational eye movements and visual acuity in order to make a step towards a predictive objective measure for visual acuity.

To do so, we determined the visual acuity of 26 subjects using a standard Snellen test, and then asked them to perform different visual tasks while their eye movements were recorded. We first report that fixation time is positively correlated with poor visual acuity, especially in visual identification tasks. We then show that the data collected can be used in machine learning algorithms to predict visual acuity. Finally, we explore deep-

learning methods that are inspired by natural language processing and computational biology In order to extract many different attributes of eye movements, visual acuity being one of them. These promising preliminary results suggest that visual acuity can be estimated robustly from fixational eye movements, possibly replacing one day the present standard tests.

Eye Movement Patterns in Visual Expertise for Print

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Objectives: Visual expertise for print refers to the reader's ability to correspond graphemes to phonemes. This ability peaks at seven after continuous exposure to words and word-like stimuli. Efficient readers can recognize and process word-like stimuli faster and more accurately than unknown symbol strings, as evidenced in event-related potential (ERP) paradigms testing the phonological mapping hypothesis (e.g., Varga et al., 2020). This study explored eye-movement patterns reflecting visual expertise for print in school-age children 8-12 years of age. It was hypothesized that distinct eye-movement patterns would be linked to orthographic stimuli and unknown letter strings, thus, reflecting processes similar to those yielded in ERP experiments.

Methods: 43 children aged 8-12 years (Mage: 9.97; SD: 1.19) were recruited. Participants performed a same-different paradigm, in which they were visually presented with pairs of pseudowords and Armenian character strings.

Results: Repeated measures ANOVAs were conducted with reading ability as the independent variable, the eye-movement indexes of fixation duration, and the number of fixations as dependent measures. Statistically significant differences were found between pseudowords and Armenian letter strings in fixation duration ($F(1,41)= 22.21$, $p<.001$) and the number of fixations ($F(1,42)= 11.08$, $p<.01$). In both instances, processing the unknown letter strings produced longer and larger values, respectively, compared to orthographic stimuli.

Conclusion: Processing unknown letter strings generates a longer processing time and a more significant number of fixations than processing known orthographic stimuli. This evidence confirms previous evidence based on ERP methods, calling for the concurrent use of eye-tracking and ERP methods in future studies.

Eye movements in facial expression recognition

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Eye movements play a functional role in facial expression recognition. Some regions of the face may contain more useful information when observing the face, depending on the expression. The question of holistic and analytic processing in facial perception is actively debated. However, less is known about inner mechanisms responsible for specific face-viewing patterns. The present research focuses on the individual mechanisms of facial expression recognition and on the identification of similar eye movement strategies (and their persistence dependent on the type of facial expression). In the facial expression recognition experiment, we analyzed responses and eye tracking data of 94 participants. Photographs of neutral, angry and happy faces from the WSEFEP database were presented separately for 2000 ms. Two extreme groups with different viewing patterns were distinguished according to the following characteristics: the average duration of fixations on the face, the number of fixations. A more detailed analysis showed significant differences in eye movements in areas of interest (eyes, nose and mouth) and revealed a tendency to use a regular sequential pattern of eye movements for the both groups. The first group is characterized by short fixations evenly distributed over three areas of interest and greater variability of the eye movement strategy when comparing neutral and emotional faces. The second group is characterized by a smaller number of fixations of a longer duration and the the use of 1-2 areas of interest while ignoring the mouth area. No significant differences in the fixation duration for the mouth area (in all facial expression) and for the nose area (in happy faces) were found.

Founded by RSCF, project number: 19-18-00474

Gaze characterization of ophthalmic lenses wearers with a new algorithm of pupil position estimation

Clara Benedi-Garcia[1], Pablo Concepcion-Grande[1], Marta Alvarez[1], Carmen Cano[1], Jose Miguel Cleva[1], Eva Chamorro[1]

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In this work, we present the development, validation, and implementation of a method to determine the areas of a progressive power lenses mostly used by the PPL wearer. It is proposed a new algorithm to estimate pupil position on ophthalmic lenses with acquired data from an eye-tracker (ET; Tobii Pro Glasses 3, Sweden; sampling frequency 50Hz; accuracy 0.6º). The new algorithm calculates de intersection coordinates of the gaze direction recorded with the ET, using also frame parameters, BVD, and IPD. Values greater than three times the standard deviation are considered outliers. Six emmetrope subjects participated in a validation trial (34±5 y/o). Two targets were placed vertically on a wall at 70cm and separated 15cm

between them. Subjects observed them through two fixed pinholes of 1.5-mm diameter during 2'' each one while head was free. Only measurements from the right eye were considered for all patients, while the left eye was occluded. Each target was watched four times. The accuracy of the measurements was 0.11mm on the lens plane. In 70.83% of the cases, the error between the pinholes' position and estimated coordinates was lower than 2mm for the horizontal component and in 91.67% for the vertical component. An estimation error lower than 4mm was found in 95.83% and 93.75% of the cases for X and Y components respectively. The position of the pinholes was contained in the pupil estimated positions in all cases (average pupil diameter 5.81±0.75mm). Thus, all results were feasible. In conclusion, it has been developed new algorithm which allows the estimation of the used area of the lenses which is already being applicated to understand how the gaze of ophthalmic lens users during different tasks.

Fixation Stability in Reading and Non-reading Task

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During the reading process, each saccade is followed by a fixation during which visual information is perceived. Fixation stability is the ability of the eye to maintain a steady and stable gaze during fixations. Previous studies have focused on the relation between fixation stability and reading performance in cases of different visual impairments, with fixation stability typically measured in non-reading tasks. However, fixation stability has not been analyzed for fixations made during reading. The aim of our study was to explore the relation between fixation stability during reading and a non-reading task where the only task was to fixate on a static target. Since fixation stability can be affected by age, eye movement records of 48 children of similar age (9-11 years, mean age 10 years) were analyzed with the Tobii Pro Fusion (250 Hz) eye tracker. Fixation stability was expressed with the bivariate contour ellipse area (BCEA). The results demonstrated that there was a correlation between fixation stability during reading and the non-reading task ($r = 0.358$, $p = 0.01$), and BCEA is significantly larger during the reading task compared to the non-reading task ($z = -4.602$, $p < 0.01$), which implied that fixation during reading was more unstable. The results suggest that fixation stability might be task-related. This study was supported by the LCS Project No. lzp-2021/1-219, the UL Project No. Y5-AZ77, and the UL Foundation Project No. 2260.

Transsaccadic perception of changes in image regularity

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The visual system compensates for the differences between the peripheral and foveal visual field using different mechanisms. Although peripheral vision is characterized by higher spatial uncertainty and lower resolution than foveal vision, observers reported peripheral stimuli to be less distorted and less blurry than foveal stimuli in a visual matching task of a previous study. Here we asked whether a similar overcompensation could be found across saccadic eye movements and whether it would bias the detection of transsaccadic changes of image regularity. We manipulated the distortion levels of simple geometric shapes in the Eidolons algorithm by systematically varying the local disarray parameter without performing scale decomposition. In a change detection task, distortion either increased or decreased during a saccade. Participants were asked to report the direction of change. Overall, they showed a tendency to report an increase in distortion across the saccade. The precision of responses was improved by a 200-ms postsaccadic blank. In a transsaccadic appearance task, participants had to estimate distortion before and after a saccade separately. Stimuli were reported marginally less distorted before a saccade (in the periphery) than after a saccade (in the fovea). The responses were more precise in the postsaccadic than in the presaccadic condition. Results from the change detection task suggest that a transsaccadic increase in distortion is more readily detected, compared to a decrease in distortion. While a previous study reported a peripheral overcompensation in the visual matching task, we found only small differences between the peripheral and foveal reports in a transsaccadic appearance task, indicating that distinct processes might be involved during a saccade.

Acknowledgements: The study was supported by Deutsche Forschungsgemeinschaft (DFG), Project number 290878970-GRK 2271.

Feature-tuned properties and underlying neural mechanisms of short-latency stimulus-driven ocular position drift responses

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We recently identified a short-latency ocular position drift response, of ~1 min arc amplitude, that is triggered by visual onsets. This systematic eye movement response occurs at a time of complete saccadic/microsaccadic inhibition, and it is predominantly upward, leading us to wonder whether it is mediated by an overrepresentation of the upper visual field in the superior colliculus (SC). To test this, we trained 3 monkeys to fixate a small, central spot (~5 by 5 min arc), and we presented a single-frame (~11 ms) black flash of either the entire upper or lower half of the display screen. We also tested a full-screen flash and a small localized flash (1 deg square), as well as other stimulus configurations (size; contrast; location). Surprisingly, all 3 monkeys showed a similar drift response for the upper and lower half-screen stimuli. Moreover, they all showed barely any drift responses to localized flashes. During simultaneous SC recordings in 2 monkeys, we observed a clear dissociation from drift response properties: SC visual responses were by far the strongest for localized flashes, and stimulus-evoked local field potential deflections differed for upper and lower half-screen stimuli, despite the similar drift responses. We then electrically microstimulated the SC of 1 monkey with transient bursts mimicking visual responses (50 ms pulse trains of 300 Hz; 30 µA). Microstimulation increased microsaccade likelihood but did not affect position drifts. On the other hand, the same monkey's omnipause neurons (OPN's) in the lower brainstem exhibited robust short-latency visual responses to flashes evoking reliable drift responses, and transient microstimulation of these neurons was associated with both complete saccadic inhibition as well as a robust eye position drift response, like with visual onsets. We conclude that there must be feature-tuned visual responses in OPN's, and that OPN activity can strongly influence slow fixational position drifts.

Spatial and temporal image statistics of fixated vs non-fixated regions in viewing artworks

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Exploration of the visual environment is an active process with the portions of a scene falling on the fovea sampled at high spatial resolution and receiving a disproportionate fraction of cortical processing. While many eye movement studies are preoccupied with the spatial distribution of selected locations, some have compared the sampled (fixated) and non-sampled (randomly selected) regions with respect to their low-level features such as luminance, spatial contrast, and high spatial frequency content (amplitude spectrum). These studies have shown that fixated locations tend to have higher spatial contrast and higher spatial frequency content than randomly selected regions.

Here we compare image statistics (luminance, RMS contrast, fractal dimension, amplitude spectrum slope and entropy) between fixated and randomly selected regions of artworks viewed in natural setting (museum) and on-screen conditions. In addition to the comparison of average image statistics between fixated and non-fixated regions, we investigate how the selection of different image statistics unfolds over time. To that end, each scanpath – a sequence of selected image regions – was transformed into a time series defined as z(t1),..., z(tN); where N is the total number of fixations, z is the observed image statistics value (RMS contrast, fractal dimension, etc.) at time t. In addition, surrogate scanpaths were generated by selecting random fixations equaling each real scanpath in the number of fixations. Finally, we calculated the auto-correlation function for each of the thus-defined time series to estimate how the selection of a particular image statistics value was dependent on previously fixated values.

As in previous studies we found that fixated and randomly selected regions differed in both spatial and temporal image statistics with more pronounced differences in on-screen viewing condition.

Coupling of eye movement to the visuospatial representations

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It is said that "the eyes are the window to the soul" and research has shown that eye behaviour can inform us of a person's aims and focus. Recent work revealed that eye behaviour differs between internally and externally directed cognition and thus is indicative of an internal versus external attention focus. However, most of these eye behaviours were moderated by the characteristics of the ongoing external and internal activities, which can be interpreted through two central cognitive mechanisms, perceptual decoupling and internal coupling. Both perceptual decoupling and internal coupling are integral components of internal attention, whereby the former refers to eye behaviour becoming disengaged from the sensory environment, while the latter describes eye behaviour coupling to the characteristics of internal events. Indeed, the literature suggests that eye behaviour is not only determined by the characteristics of sensory stimuli, but also couples to the mental representations. In the present study we systematically investigated coupling of saccades to internal representations and examined the strength of these effects in both visual perception and mental imagery (visible and invisible reference grid, respectively). We

further assessed the role of potential moderators of internal coupling including workload (low, high), task type (control, semantic oddball, visuospatial navigation), and directionality (horizontal, vertical). Initially, data of 50 participants will be analysed with mixed effect models to establish whether the visuospatial navigation task induces coupling of eye movements. In case of positive results in the mental imagery condition, irrespective of other moderators, additional 100 participants will be recruited to assess individual differences in working memory and imagery abilities as potential moderator of the effect. The findings will contribute to a deeper understanding of the mechanisms underlying internal attention, shed light on relevant conditions of internal coupling, and the role of eye behaviour in this process.

WALD-EM: Wald Accumulation for Locations and Durations of Eye Movements

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Describing, analysing and explaining patterns in eye movement behaviour is crucial for understanding visual perception, and eye movements are also becoming used more frequently in informing cognitive process models. As such, formal models of eye movements are needed to integrate empirical research with theory and underlying cognitive processes.

Here, we identify several desiderata for models of eye movements such that they are useful both in the theoretical and empirical research cycle. Specifically, generative models make it possible to verify that the theoretical assumptions built into the model produce empirical phenomena observed in real data. Statistical and modifiable models facilitate discovery and quantification of novel phenomena (through parameter estimation and model comparison), or test alternative explanations for already existing empirical observations. Finally, spatio-temporal models gain importance as they explain the when and where questions of eye movements and have the potential to capture the relationships between the two.

The present work showcases the development of a new model of fixation durations and fixation locations meeting the desiderata we identified. The use of the model is demonstrated in an example of infant natural scene viewing and demonstrates a flexibility of the model to adapt based on additional empirical phenomena detected in the data. Potential future avenues and applications of formal eye movement models are discussed.

Fixational eye movements form fine stereoacuity

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Stereo vision creates representation of disparities between projections to the two retinae. The disparities change with fixational eye movements (FEMs) occurring within fixation. In experiments, short presentation times, and instructions to observers, minimise the effect of FEMs. Yet, there is an elephant in the stereo experiment room since many repeated trials are usually required (e.g. the method of constant stimuli).

Two psychophysics studies using 3D stimuli (lines, and line segments connected in a contour) projected with a stereoscope and a single monitor were self-replicated with the addition of simultaneous eye tracking at 1000 Hz in binocular mode. Observers reported perceived relative depth, and demonstrated stereoacuity up to 0.01 arcmin. For most observers (N=17 in two studies), the horizontal disparity stereoacuity threshold was less than fixation precision between trials of one block. We concluded that distinct FEM patterns allow for fine stereoacuity only along distinct directions. Indeed, observers' responses could be predicted by an alternative disparity function accounting for FEMs as if following a Donders' law. The law potentially helps to assign a common solution to all pairs of projections formed from a scene during the limited set of possible FEMs.

FEMs for similar stimuli depended on the stimuli parameters and on responses, what could be partly attributed to covert attention. For example, for line segments tilted from vertical, observers' psychometric curves were biased in opposite directions depending on the tilt. Their gaze position distributions were also biased in opposite directions and significantly different (e.g. the means). Moreover, the change in stereosensitivity for line segments compared to the segments in a contour as well as intersubject variability could be explained by different FEM distributions.

The results challenge standard experimental methodology as FEMs may corrupt stereo stimuli not corrected in gaze-contingent manner. And importantly, the results strongly support the active vision paradigm.

Effects of the nature of the context on contextual saccadic adaptation

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Contextual saccadic adaptation is studied with a variant of the double step paradigm, in which two different contexts signal the possible directions of the intra-saccadic step (ISS). This allows to simultaneously inducing two distinct saccadic adaptation states. For instance, when using saccade direction as context, the gain of rightward saccades may be increased while the

gain of leftward saccades is decreased. Importantly, effective contextual adaptation is not always observed: e.g. it occurs when the amplitude of the first target step serves as context, but not when using the target color or shape. Here we compare the efficacy of different types of contexts. All experimental sessions are based on the same contextual adaptation paradigm, the only difference being the context used. We tested nine different contexts: (1) the duration of a visual stimulus, (2) the lateralization of a sound in space, (3) the pitch of a sound, (4-5-6) the statistical regularity across trials and (7) a symbolic cue, as well as (8) the amplitude of the first target step and (9) the target color and shape to compare our results with previous studies. We collected data from 90 participants. Fisher's test revealed contextual adaptation in the 'first target step amplitude' condition in all participants, and no systematic effects in any other condition. The Kolmogorov-Smirnov distances indicate large contextual effects for the amplitude, but not for any other contexts. This lack of contextual learning reveals that predicting the intra-saccadic step is surprisingly difficult and strongly depends on the nature of the actual context, even for highly salient contexts: perfect correlation between the contexts and ISS is not sufficient for learning, even for non-visual contexts. A similar effect, termed selective learning or biological constraints on learning, has been previously reported in pavlovian and operant conditioning animal studies.

Exploring the Relationship Between Gaze and Movement Transitions During Natural Human Walking on Different Terrains

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Understanding and predicting human walk behavior is an important prerequisite for a proper design of physical assist robot control. One challenge for such systems is the accurate and timely prediction of walk transitions. To improve models based on gait behavior only, prior work has investigated the effect of exploiting visual sensor data. Only few works have included human visual behavior, even though gaze plays a significant role for successful goal-directed locomotive behavior and, therefore, may have the potential to significantly improve predictions of changes in walk modes. In this study, we investigate the potential of using estimates of human gaze behavior for improving walk transition models based on a publicly available real-world data set including IMU motion data from an Xsens motion suit and gaze data from the Pupil Labs Invisible mobile eye tracker. 20 participants completed two outdoor walking tracks including three different types of walk modes: level walking, stairs (up, down) and ramps (up, down). As a first step, we analyzed whether we would find changes in gait and gaze parameters as a function of changes in walk mode. We hypothesized that a change in viewing behavior may be detected earlier than a corresponding change in gait parameters. To analyze the proportion of gaze behavior directed towards the ground, we investigated the vertical deviation in head angle as a first proxy. First results suggest that gait parameters, e.g. average step length, change up to two steps before a transition phase. Average changes in vertical head angle precede those up to three steps. Effects are more pronounced in transitions involving stairs than in those involving ramps. As a result, we conclude that the time horizon for predicting walk transitions could be considerably extended by including estimates of human gaze behavior in a multimodal model of gait behavior.

Comparison of saccades in athletes and non-athletes

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Saccadic eye movements play an important role in success of the athletes especially in dynamic sports. Therefore, various studies try to understand if athletes have better saccades due to regular indirect training of visual abilities (in regular sport activities) compared to non-athletes. However, results are contradictory if we look on various saccadic eye movement types. There are studies demonstrating that saccadic movements have shorter saccadic latency, higher special accuracy, and velocity of prosaccades in athletes. However, other studies demonstrate that latency is different only for antisaccades and not prosaccades. The aim of this study was to evaluate quality of prosaccades in athletes and non-athletes. The study included 100 participants: 50 athletes and 50 non-athletes. Eye movements were recorded using the non-invasive video-oculography technique (EyeLink 1000 plus eye tracker). Black dot on a grey background was used as the saccadic stimulus. The stimuli appeared randomly in the horizontal (10° and 5°) or vertical (6° and 3°) direction relative to the initial position (center of the screen). Each stimulus position was repeated 3 times. The analysis showed that athletes had more symmetrical saccades in both horizontal directions (left and right) compared to non-athletes where larger amplitudes and inaccuracy was observed on the right compared to the left side (mixed model ANOVA: $F(1,98)=6.985$, $p=0.01$). There was no difference between athletes and non-athletes in vertical direction. Velocity of saccades showed no difference between athlets and non-athlets ($p>0.05$). In conclusion, athletes demonstrate more symmetrical saccades compared to non-athletes in horizontal direction.

Acknowledgement. Supported by Project Research and Application Methodology Development of a New Preventive Eye Muscle Training and Strengthening Device EYE ROLL (No. 1.1.1.1/20/A/038).

Developing an Indicator of Cognitive Load Using Pupillometry

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Pupillometry can be a used to assess cognitive load. To investigate the sensitivity of pupil dilation as a measure of cognitive load we used the auditory N-Back paradigm. We were interested to investigate the relationship between cognitive load and pupil dilation on a per trial basis. Ten participants completed three levels of the N-Back task (n-1, 2, and 3) with each condition comprising 100 trials. On average, we were able to identify within trial pupil dilations which positively correlated with task difficulty (acute pupil response). We were also able to identify larger dilations across each N-Back condition (tonic pupil response), with a positive correlation between task difficulty and baseline pupil size. For both types of pupil responses, the largest dilation occurred during the most difficult task (3-back). We also found that the tonic pupil size showed a constriction across trials, which may indicate increased task efficiency or reduced effort.

Other performance measures, reaction time and accuracy, suggest increased task efficiency across trials while completing the 1- and 2-back and reduced effort during the 3 back. Reaction time decreased over trials for all N-back difficulty levels, however in contrast to maintained accuracy during the 1- and 2-back conditions, accuracy decreased across trials for the most difficult task (3-back). Overall, our findings suggest that pupil dilation could be a sensitive indicator of the level of per trial cognitive load while completing the N-Back task. However, our results also highlight the necessity of considering multiple performance measures when assessing cognitive performance in this way. This suggests further research is needed to explore the potential applications of Pupillometry with a focus on not only the dilatory response but also the temporal pupil dynamics, including analysis in the frequency domain.

Vision relaxation with a new device EyeRoll

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With the development of new technologies, the number of persons increases that feel discomfort and have asthenopic complaints after working with digital devices. Various vision relaxation exercises are mentioned as one of the most effective ways to reduce asthenopic complaints. They are described on various websites and demonstrated in many apps. However, there is a lack of (1) special devices that would allow to perform vision relaxation in a free space and (2) studies that objectively demonstrate changes after performance of these exercises. The purpose of the study was to evaluate the efficiency of the new device EyeRoll (that guides vision relaxation exercises in a free space). Fifty-four participants were evaluated for clinical, subjective and objective changes before and after 1 month: questionnaire to evaluate working habits and everyday activities, full eye and vision examination, accommodation evaluation (PowerRef3) and saccadic movements (EyeLink 1000+). There were three groups of participants: control group – no exercises, training group 1 – vision relaxation training without any devices, training group 2 – vision relaxation training with EyeRoll device. The results demonstrated that there were no statistical changes in objective measurements such as amplitude of accommodation and saccadic movements, as well as clinical measurements (visual acuity, binocular and accommodative function) in each group after 1 month. The results demonstrated decrease in a set of asthenopic complaints (such as vision discomfort, eye pain, dryness, eye fatigue, difficulties focusing) in both training groups (no changes were observed in the control group). Vision relaxation exercises (both manually or with the device) can be used to decrease asthenopic complaints after working on computer. The EyeRoll device was preferred by the participants thanks to the guided relaxation process.

Acknowledgment. Supported by Project Research and Application Methodology Development of a New Preventive Eye Muscle Training and Strengthening Device EYE ROLL (No. 1.1.1.1/20/A/038).

Dissociating temporal expectations in the perceptual and oculomotor domains

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Humans are adept at detecting temporal regularities in sensory input and exploiting predictable stimulus timing to improve perceptual and motor performance. Several behavioural manifestations of temporal expectation have been identified, however it remains unclear whether they are governed by a common centralised timing mechanism or multiple distributed mechanisms. Here we compared two indices of temporal expectation within a single task - oculomotor inhibition and contextual calibration of time perception. Observers performed a 'ready-set-go' temporal reproduction task, whilst attempting to maintain fixation in the centre of a visual display. Performance was assessed under conditions where the 'ready-set' stimulus interval (demarcated by two brief visual stimuli) either remained constant within a testing session (800ms, 1200ms or 2000ms), was sampled from a discrete uniform distribution (ranging from

800-1200ms or 1200-2000ms) or randomly/sequentially alternated between two extremes (800ms & 2000ms). In keeping with previous studies, analysis of fixational eye movements within the stimulus interval revealed systematic inhibition of saccades prior to the appearance of the second stimulus. The depth and timing of this inhibition reliably indicated the expected temporal interval and was sensitive to manipulations of stimulus sequence. Observers' reproductions were also characterised by strong central tendency effects, consistent with integration of timing estimates with expectations based on cumulative experience. However, in contrast to their oculomotor counterparts, these inferred expectations appeared rudimentary, approximating the mean of previous stimulus intervals regardless of whether the presence of higher-order temporal structure allowed for exact prediction. Our results reveal a dissociation between these perceptual and oculomotor effects, raising the possibility that multiple domain-specific forms of temporal expectation coexist in the human brain.

Pupil Size Reveals Imagination: Pupillary Response in Visual Imagery

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Visual imagery has a long history in psychology. Visual imagery is thought to share some features with visual perception. However, the mechanisms underlying visual imagery remain unclear. Reliance on self-report subjective responses in the measurement of imagery may have hindered the research progress on this topic. Kay, Keogh and Pearson (2022) proposed to use the magnitude of pupillary light reflex during imagery as a measure of imagery vividness. In this study, we aim to replicate Kay et al.'s (2022) findings and to further explore the relationship between such pupillary measure and subjective self-reports of imagery experience. Twenty-five normally sighted participants were asked to view 16 stimuli in four luminance levels, which were grouped into "Dark" vs. "Bright" stimuli, and then imagine the previously seen stimulus. We measured pupillary responses during both perception and imagery periods. Robust pupillary light response was observed both in the perception period ($F(1,24) = 120$, $p < .001$), and in the imagery period ($F(1,24) = 5.79$, $p = .024$). Post hoc comparisons revealed that when the stimuli were presented during perception, pupil size (relative to baseline) was significantly larger in response to Dark Stimuli, $M = 1.36$, $SD = 0.64$, than the Bright Stimuli, $M = –1.37$ $SD = 0.79$, $p < .001$, $d = 2.19$, 95% CI [1.45, 2.91]. During imagery, pupil size was significantly larger in response to Dark Stimuli, $M = –0.07$, $SD = 0.41$ than the Bright Stimuli, $M = –0.35$, $SD = 0.58$, $p = 0.024$, $d = 0.546$, 95% CI [0.06, 0.89]. Pupillary light response was observed not only during perception but also during imagery. We also explored the relationship between this pupillary measure and three self-report measures of imagery vividness. Our findings could be interpreted as a result of overlapping mechanisms behind both perception and imagery.

Is Eye Movement Latency Variation as a Predictor of Cognitive Impairment ?

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Numerous studies have demonstrated abnormal saccadic eye movements in Alzheimer's disease (AD) and people with mild cognitive impairment (MCI) when performing pro-saccade and antisaccade tasks. Research has shown pro and antisaccade latencies can predict cognitive ability and can indicate executive functioning deficits. These tasks show potential for diagnostic use as they provide a rich set of potential eye-tracking markers. One such marker, the coefficient of variation (COV), has so far been overlooked. For biological markers to be reliable they must be able to detect abnormalities in preclinical stages of the disorder. MCI is often viewed as a predecessor to AD with certain classifications of MCI more likely than others to progress to AD. The current study examined the potential of COV scores on pro and antisaccade tasks to distinguish participants with AD, amnestic MCI (aMCI), non-amnesiac MCI (naMCI) and healthy older controls. The analyses revealed no significant differences in COV scores across the groups using the antisaccade task, however COV scores on the prosaccade task showed promising results in distinguishing people with MCI from older controls. MCI groups showed higher COV scores indicating greater attentional fluctuation when compared with older controls. Interestingly, this distinction was not found in the AD group. Antisaccade mean latencies were able to robustly distinguish participants with AD and between the MCI subgroups showing high sensitivity. Future research is needed into COV measures and attentional fluctuations in AD and MCI individuals to fully assess this measures potential to robustly distinguish clinical groups with high sensitivity and specificity.

Effect of eye movements and finger pointing on auditory spatial perception

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Eye movements are intimately associated with spatial attention. In behavioral experiments, eye movements facilitate spatial attention in both visual and auditory domains. Neurological evidence has demonstrated the importance of the superior colliculus in spatial attention, integration of inputs from visual,

auditory, and somatosensory information and feedback controls movement of the body. Even though these functions are known to relate by anatomical structure, there are only a few studies that explored the effect of body movement, especially its interaction with eye movement on spatial attention. To investigate the effect of eye and body movement on auditory spatial attention, we employed Posner's cueing paradigm with sound localization task to study the effect of attention modulation through the uses of eye movement and finger pointing. Results from 11 normal-hearing participants revealed the benefit of attention on sound localization in valid trials compared to invalid and neutral trials in reaction time, but not in accuracy ($F = 8.369$, $p = 0.008$ and $F = 0.918$, $p = 0.416$ respectively). To measure attentional benefit, we compared the difference of reaction time between valid and not-valid trials (invalid trials and neutral trials). Main effects of eye movements and finger pointing facilitate spatial attention were found ($F = 13.484$, $p = 0.003$ and $F = 6.861$, $p = 0.022$ respectively). Participants can locate the sound source faster when their gaze or their right index finger is pointed to the ipsilateral side of the sound compared to the contralateral side. Accuracy between each side was similar. An interaction between eye movement and finger pointing were not seen ($F= 0.651$, $p = 0.436$). Our findings suggest that, apart from eye movements, body movement like finger pointing has influences on auditory spatial attention which improves auditory spatial perception. This could benefit further study on neural mechanisms and the linkage between the superior colliculus and attention networks.

Predicting Multiple-Target Search Performance Using Eye Movements and Individual Differences

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Accuracy in visual search – the process of detecting a target amongst distractors – is critical for life-saving career searches such as radiology and airport security. These searches often contain multiple targets (e.g., a tumour and a fracture) and are prone to cognitive pitfalls such as "subsequent search misses", where second targets are less likely to be identified in the presence of a previously detected target. Prior work has assessed individual differences in search performance, and some research has also identified eye movements associated with search errors; however, the complex relationship between observer characteristics and search strategies that may predict performance on multiple-target search tasks remains an open question. To assess the relationship between individual differences, underlying cognitive mechanisms, and search performance, we tested novice (undergraduate) participants on a multiple-target visual search task while monitoring their eye movements. Participants were required to conduct a serial search of displays containing 0, 1, or 2 target 'T' shapes (amongst distractor 'L' shapes) that varied in visual salience and confirm identification of each target via a mouse-click. After the multiple-target search experiment, participants completed a series of questionnaires on their personality traits, clinical characteristics, and hobbies/experiences related to visual attention (e.g., video gaming and sports). We present comprehensive analyses on the impacts of individual differences and search strategies on the speed and accuracy of target detection for single- and multiple-target search. We found that both observer-related traits and specific patterns of eye movements predict search speed and accuracy across a variety of target types. Our results have implications for which search behaviours are most effective for optimal accuracy and how the strategies adopted may interact with personal characteristics. These findings can directly inform the assessment and training of people with search-related careers and allow for individualised approaches to improving search accuracy.

Sight translation in L2: evidence from eye-tracking

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The study aims to answer two questions: does reading type (oral vs. silent) contribute to L2 text perception quality, and what type of reading is more advantageous for successful sight translation. According to Andrea D. Hale et al. (2007), reading aloud facilitates understanding of the text, despite the fact that it requires to exert more cognitive effort for a reader. Fuchs et al. (2001) suggested that aloud reading fluency represents the overall reading competence. In our two-group experimental design, 20 Russian native speakers were reading two English texts (aloud or silently). They were asked to translate them from English into Russian. Both texts were of the same length, topic and readability. The participants eye movement patterns during the pre-reading task have been recorded. We have measured the reading duration (RD), total fixations amount (TFA), average fixation duration (AFD), and total amount of regressions (TRA). The sight translation quality of each participant have been assessed with the use of Gilmullina's (2016) sight translation quantitative analysis method. Mann-Whitney U test has shown that when subjects were reading aloud, they were reading significantly slower (RT: p=0,008; TFC: p=0,027; AFD: p=0,036; RC: p=0.134), as opposed to silent reading duration. No significant correlation between sight translation quality and subjective difficulty of text perception (oral reading vs silent reading) was found. However, we have found that despite the fact that aloud reading does not affect text perception significantly, though it delays the promptitude of sight translation, since it requires more time on text processing. This way we have found that aloud reading type is less time efficient and therefore the least preferable for this type of action. We also assume that aloud pre-reading type does not threaten the overall quality of sight translation. This means that the text availability does not affect

the interpreter's performance, but contributes to it. The study is supported by the research grant no. ID92566385 from St Petersburg University.

Development of functional spatial span measure in reading

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The magnocellular visual system plays a pivotal role in the ability of reading. It is involved with planning saccadic movement, and a possible dysfunction in this step of visual processing may explain certain subtypes of developmental dyslexia. Eye-tracking measures have found the saccade time for reading is around 150 ms. Our goal was to develop a clinical assessment to analyze functionally the saccade in reading. The test consists of a syllabic reading task, in which we presented sequentially 40 pairs of syllables on a computer screen. We used Arial 14 font, which comprises a 0.25° visual angle. It always presented the first syllable at the center of the screen, while it may show the second syllable in four different positions: 0,5°; 1,5°; 3°and 6°of horizontal eccentricity to the right of the central position. The syllables are randomly chosen and the interval between the appearance of the first and the second one may be 120 ms (functional saccade condition) or 240 ms (control condition). We assessed 18 undergraduate students, ranging from 19 to 29 years old (M= 23,5; SD= 2,9), with normal visual acuity or corrected to normal and absent of any known ophthalmological diseases. The average reading threshold for 120 ms is 5.48° (SD= 1,1) of eccentricity; for 240 ms the rate of correct answer was above 90%. Albeit the number of participants is below what we expected, the results show our methodology ought to have an untapped potential for assessing spatial span in reading. The high rate of correct answers obtained for 240 ms confirms the typical performance in executing a reading task. This clinical assessment has noticeable potential for investigating reading and school performance difficulties.

The use of progressive lenses while going upstairs or downstairs: an eye-tracker study

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When using progressive lenses, presbyopes find more challenges when facing dynamic situations in which the scene is shifting or rocking, such as going up and down stairs. Understanding how PPLs are used during these tasks will help to improve lens design. This study aims to evaluate changes in eye-movement when subjects go up and down stairs by utilizing eye-tracking technology. In addition, the area of the lenses used in this test has been calculated for the first time. 31 subjects participated in an observational longitudinal doubled-mask study. They walked through a 10-step flight of stairs up and down while wearing two pairs of Free-Form lenses: Endless Steady Near and InMotion (Indizen Optical Technologies, S.L.). The pupil position was recorded with an eye-tracker (Tobii Pro Glasses 3, Sweden). Eye movements were analyzed (Task time, Fixation time, Saccade time, Fixation rate, Number of fixations, and number of saccades) and the intersection of the gaze direction with the lens surfaces was registered with a frequency of 50Hz. The area of the lens used during the experiment was determined as the smallest square circumscribing the convex hull of all the intersection points. It was found that participants take longer (p-value<0.001) and need to fixate more times (p-value<0.001) when going downstairs. Regarding lens design, participants needed less time (p-value=0.03), lower saccade time (p-value=0.001), fewer fixations (p-value=0.006), and fewer saccades (p-value=0.006) while using Endless Steady Near. Also, the average size of the area of the lens used by the participants was smaller with the Endless Steady Near design, both when going up and down. In conclusion, there are differences on vision strategies depending on whether the stairs are walked up or down as well as on the type of PPL that is worn. These findings can be used to improve the power distribution of PPL designs.

Robust storage for a large variety of stimulus features across saccades, but not across peripheral-to-foveal retinal shifts during fixation

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When our eyes dash to an object of interest, small changes to the object's features during the movement usually go unnoticed. Recent research demonstrated however that a brief blank of the object during saccade execution strongly increases performance. For example, blanking increases discrimination performance of orientation changes. This demonstrates that blanking makes pre-saccadic object information available that observers could otherwise not access. Despite the importance of the blanking effect for understanding transsaccadic perception, the effect was studied with a very limited number of parameters and features. For example, it remains unclear under which circumstances blanking fails. Here, we investigated the effect with a range of stimulus sizes, spatial frequencies, and target eccentricities in conditions with and without eye movements.

We conducted two experiments in which participants made saccades to peripheral gratings. Targets appeared at different eccentricities (6, 8, 10 degrees), with various sizes (1, 2, 4 degrees) and spatial frequencies (0.5, 1, 2, 4, 8 cycles/degree). Upon saccade detection, targets were rotated and presented at the same location either immediately or after a 200 ms blank. Participants judged the direction of that orientation change as either clockwise or counterclockwise. Additionally, in a fixation condition mimicking the peripheral-to-foveal retinal shift of the saccade condition we investigated whether feature blanking effects are contingent upon eye movements.

Remarkably, in the saccade conditions, we found discrimination performance benefits of blanking across all eccentricities, spatial frequencies, and sizes. In stark contrast, in the fixation condition the performance increase was absent across all conditions tested. In fact, performance during fixation was lower than in the blanking condition for saccades, suggesting that the mechanism underlying the feature blanking effect is contingent upon saccade execution. The striking robustness of the effect indicates that a broad range of stimulus information about saccade targets is potentially available across the movement.

Supported by European Research Council (grant No 865715) and Deutsche Forschungsgemeinschaft (grants RO 3579/8-1 and RO 3579/12-1) granted to MR.

Pupillary responses to perceived glossiness and attractiveness

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Changes in pupillary responses are influenced by luminance and perceptual factors, such as subjective brightness in optical illusions. A recent study reported that pupillary responses are associated with perceived glossiness, where high-gloss images constrict pupil size to a greater degree. In terms of material perception, such perceived glossiness and transparency are considered to derive from physical surface properties, and they subsequently influence higher level emotional responses, such as attractiveness and preferences. If this hierarchical structure explains the process of sensory inputs in the visual system, physical and emotional attributes should temporally differentiate during material perception. Thus, we hypothesized that this temporal alternation appears as related signals in pupillary responses. Here we investigated whether perceived glossiness and attractiveness affect pupil diameter and compared their dynamics. The stimuli used were general object images from the THINGS database, referencing a previous study. The image features of the stimuli were controlled using luminance histogram matching and it was presented for three seconds. Participants were asked to rate perceived glossiness and attractiveness across different blocks, and pupillary changes were recorded concurrently. We found that pupils constricted more for high-gloss images than low-gloss images at the pupillary light reflex of the stimulus. This result replicated previous findings, and the amount of constriction was approximately equivalent to the pupillary changes from the brightness illusion. In contrast, the high-attractive images caused pupil dilation later during the stimulus. This means that emotional responses, which interpret things as attractive, are associated with high arousal and lead to pupil dilation. This suggests that pupillary responses initially reflect the perceptual factor of perceived glossiness triggered by the pupillary control system, and subsequently receive feedback signals relevant to higher-order processing from the ventral pathway.

Verbal labels influence target identification process in visual search

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Visual search in real world is far more complex than in the laboratory. People widely use verbal labels to describe search targets in daily life. However, the influence of verbal labels on visual search remain unknown. Although researches are pretty sure that verbal labels have no influence on guidance (Wolfe, 2021), we suppose that verbal labels could influence target identification process. Due to rehearsal processes a verbal label could increase the activation of search template held in working memory. And this additional activation would prevent interference with other information and thus facilitate target identification. So, we hypothesized that dwell time for targets with labels would be shorter than for targets without labels. As the stimuli we used pictures of eight species of butterflies. Four of them were provided by the verbal labels, used as species' names. On the first stage of our experiment participants learned to distinguish those species and learned their names (for a half of them). On the second stage participants perform a visual search task and their gaze data was collected using eye tracker EyeLink Portable Duo (1000 Hz). A target was designated by the picture and the word simultaneously (specie name for labeled categories, "butterfly" for non-labeled categories). 23 volunteers (3 males) participated in our study. Repeated measures ANOVA revealed significant difference of dwell time between targets with labels and without labels $F(1,19) = 6.62$, $p = 0.02$. Dwell time for targets with labels was longer than for targets without labels, which contradicts to our hypothesis. Verbal labels increase target identification time. Perhaps verbal labels activate some additional visual features of related object which increase the amount of information for comparison during target identification.

I spy with my little eye… an anchor object! How anchor objects modulate eye movements during visual search

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We live in a complex world where object arrangements in scenes follow specific rules captured by a so-called scene grammar that helps navigate our environment. In this hierarchical network of object-to-object and object-to-scene relations, different objects take on different roles: Smaller local objects (e.g., toothbrush, toothpaste) cluster around larger anchor objects (e.g., sink) to form phrases. During real-world visual search, anchors guide our attention toward local target objects. This study aims to directly probe the hierarchical relations of anchor and local objects within and between phrases in the absence of real-world scene guidance (e.g., surfaces, layout). Participants (N=32) performed a visual search task while eye movements were recorded. Each search display consisted of 12 real-world objects arranged in a circular array. All targets were local objects while the critical distractor object was an anchor . To probe the hierarchical relationships between anchor and local objects, we varied the level of relation between target and distractor: related (same phrase, e.g., toothbrush and sink), unrelated (different phrase, same scene, e.g., toothbrush and shower), and semantically unrelated (different scene, e.g., toothbrush and bed). We expected distractors from the same phrase to be more distracting than from a different phrase or even different scene. We found significant differences in reaction times between the related and the semantically unrelated anchor as well as in the number of fixations: related anchors were fixated more often than semantically unrelated anchors. There were no significant differences between related and unrelated anchors. The phrasal structure of local and anchor objects in scenes was therefore only partly /not reflected in eye movements. The activation of hierarchical relations between different object types might require the presence of actual scenes. Further research is needed to look into when exactly which parts of these hierarchies are activated in which context.

Individual differences in gaze strategies when performing the same task: an example from stair climbing

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It has been assumed that the task determines where people look, as it constrains where currently useful information is to be found. When walking on a staircase, one must consider the positions of the steps. Nevertheless, research on stair climbing has revealed that the extent to which people look at the steps is very variable. A possible reason for the variability is that people readily rely on peripheral vision to execute the task, making where they fixate less critical. If so, occluding part of the staircase might reduce the variability in the gaze pattern between people by making looking at individual steps more relevant. We tested this by asking people to walk up and down several staircases, either with or without a tray with two cups of water on it. Holding a tray obviously occluded part of the staircase. When carrying the tray, people shifted their gaze across steps in much the same way as they did when walking without the tray. There was still a lot of variability in the number of fixated steps. We found a positive correlation between the fraction of fixated steps when walking with and without the tray, suggesting that the differences between people is really in their use of visual information about the steps. In addition to the variability in the number of steps that they fixated, people also differed in how they held the tray, and therefore in where they looked at the staircase relative to the tray. Overall, people most frequently looked above the tray when walking up and below the tray when walking down, but there were differences in this too. Thus, even when performing daily tasks that clearly rely on visual guidance, where people look is only loosely determined by the task, with a lot of variability across individuals.

Looking versus searching: Inhibition of return in an extended saccade sequencing paradigm

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There is evidence that suggests that the extent of saccadic inhibition of return (IOR) depends on characteristics of the task. We investigated this proposition in the framework of an extended saccade sequence paradigm, originally developed by Ludwig et al. (2009). We compared a task that required participants to merely follow a cue through a display ("looking" task) with a task in which they followed the cue and had to decide whether a pre-specified target letter was present at the cued location ("search" task). This also allowed us to test for the time course of IOR. The display consisted of 16 circles as possible fixation locations. The circles contained a small letter, identifiable only by fixation. In the "looking" task, the letter was to be ignored. In the "search" task, the letter was either a pre-specified target or a distractor. The gaze of the participants was guided by an exogenous cue, the highlighting of the circle that was to be fixated next. After the sixth fixation in the sequence, the gaze was either directed back to a location fixated up to

five fixations earlier (fixation lag) or directed to a new location. After a variable number of additional saccades, participants were directed to a circle containing the pre-specified target letter ("search" task) or to a circle where they had to make an orientation judgment ("looking" task). In both cases they then responded manually. For both tasks, we found longer saccade latencies for all five fixation lags compared to latencies of saccades to new locations. This result indicates the presence of a long-lasting effect of saccadic IOR but no effect of the task. We discuss various task demands in the context of the saccade sequencing paradigm.

Does individual gaze lead to individual visual representations?

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Previous research has found evidence for a shared geometry of movie representations across brains. Hyperalignment is a machine-learning technique to compare such geometries across individual brain topographies and allows cross-brain decoding of movie snippets from inferior temporal cortex (IT) far above chance (Haxby et al., 2011, Haxby et al., 2020). However, decoding performance is also far from perfect. Here, we asked whether errors in hyperalignment are purely due to measurement noise or reflect genuine individuality of neural representations. We hypothesized that individual differences in eye movements (e.g. Bargary et al., 2017; de Haas et al., 2019; Constantino et al., 2017; Broda & de Haas, 2022) lead to systematic divergence of neural representations beyond topography. First, we found that individual saccadic rates and amplitudes towards a feature film ('Shaun the Sheep') varied up to factor 2 (n = 38) in an eyetracking experiment. Then, we used functional MRI in a subset of participants (n = 14) to test how predictive inferior temporal representations of one observer were for those of another, in two conditions. Participants watched movie segments either freely moving their eyes or fixating centrally. We then used a customized version of hyperalignment to test cross-decoding accuracy, separately for each pair of observers and condition. Results showed that the amplitude of BOLD responses dropped significantly for central fixation compared to free-viewing ($t = -4.63$, $p < .001$, across IT). Nevertheless, cross-decoding performance significantly increased from 38% to 63% ($t = 11.27$, $p < .001$). We conclude that individual eye movements enhance the neural signal evoked by visual stimulation, but also lead to more individual representational geometries. Our next step will be to disentangle the contribution of different gaze parameters to the inter-individual divergence of neural representations.

A pupillometry study of reward and uncertainty in exploratory decision making

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Changes in pupil diameter have been used as physiological markers for many cognitive functions. In learning and estimation, pupil metrics have been linked to cognitive variables such as expected reward and uncertainty. However, it is less well understood how these pupil-reflected factors contribute to exploratory decision making in a stochastic and volatile environment. The goal of this study is to investigate, through behavioral and pupillometric data, how uncertainty and reward jointly govern the exploration-exploitation trade off in decision making. We present data from a two-armed bandit paradigm, in which there are interleaved free- and forced-choice trials and occasional changes in reward contingencies (change-points).

We find that the pupil is indeed modulated by both expected reward and uncertainty, but in a complex and choice-dependent way that reflects how different forms of uncertainty contribute to exploratory decisions over time. For example, after a block of forced trials, pupil size is more correlated with expected uncertainty (EU), which is thought to reflect observation noise and inferential uncertainty. Consistent with the pupil, subjects are more likely to explore the option with high EU during the first free trial following forced trials. On the other hand, after change-points, in which the mean reward rate jumps from one level to another, pupil responses are more correlated with unexpected uncertainty (UU), which scales with the extent to which outcomes violate expectations. Behaviorally, subjects readily switch choices after change-points, and the magnitude and timing of the transient pupil response reflect when the behavioral switch happens. Moreover, we observe individual differences in pupil metrics: subjects who switch less often between options exhibit larger pupil dilation in response to a decreasing outcome on the same option, compared to an increasing outcome. These findings suggest pupillometry measures as a valuable tool for revealing uncertainty- and reward-related factors driving learning and exploration.

Pupil responses reveal detection rates beyond reports in choice blindness

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Previous behavioral experiments revealed that when people receive false feedback about intended choices, they often fail to notice the mismatch, accept the outcomes, and confabulate reasons as to why they did so. This "choice blindness" phenomenon has been repeatedly observed in the past and also across different modalities. However, all prior studies relied on subjective reports to determine whether a manipulation was detected or not, leaving open the possibility that participants noticed changes without explicitly reporting them. Here, we used computerized versions of the choice blindness paradigm together with eye-tracking to investigate if pupil responses could serve as an objective physiological response that reflects subjects detection of manipulated trials. Our results of two experiments revealed high concurrent and retrospective detection rates and increased pupil dilation during all manipulated trials, irrespective if they were detected or not. This mismatch between pupil responses and reporting behavior casts doubt on previous studies relying on self-report as a measure of detection and suggests a general overestimation of the prevalence of the phenomenon.

Microsaccade size reflects spatial demands on internal selective attention in the oculomotor system

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It is well established that spatial attention can bias the direction of fixational saccades. It remains unknown whether and when attention may also bias the size (amplitude) of fixational saccades. To investigate this, we cued attention to one of multiple items in visual working memory while manipulating the spatial demands on attention. In one condition, trials contained two colored tilted bars (presented to the left and right) that were both either near or far from fixation. A color cue (presented during the delay) instructed participants to select either memorandum. Additionally, we included a load-four condition in which items occupied the near and far locations on both sides. Critically, in these trials, the direction is not sufficient to select the cued memorandum as there are always two memoranda in the same direction (one near, one far). Consistent with prior work, we confirm that the direction of fixational saccades was robustly biased by the memorized location of the attended memorandum. More importantly, our data reveal that the size of the directionally biased fixational saccades was also modulated by the spatial demands on attention. Specifically, fixational saccades became larger when selecting the far item, but only when direction was insufficient.

Temporal dynamics of size constancy for perception and action with real objects at real distances

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As we watch a train depart from a platform at a railway station, the size of its image on the retina gets smaller as it moves further away from us. Although the train is shrinking on our retina, we perceive it as exactly the same size, but just moving further from us. This perceptual rescaling of size to counteract the natural shrinkage of an object's retinal image with increasing distance is known as size constancy. Size constancy is critical not only to our perceptual experience, but also to our successful interactions with the physical and social world. Yet, our understanding of when and where the complex integration between size and distance information takes place remains unknown. Here, we recorded for the first time event-related potentials (ERPs) in conjunction with kinematics while participants were asked to either manually estimate the perceived size of an object (perceptual task) or to pick it up (grasping task). Small and big disks were placed at near and far distances, respectively, in order to subtend the same visual angle on the retina. Participants were asked to maintain their gaze steadily on a fixation point throughout the experiment. Meanwhile EEG was recorded from 64 scalp electrodes and their hand was tracked with a motion capture system. We focused on the first positive-going visual evoked component peaking at approximately 90 ms after stimulus onset. We found earlier latencies and greater amplitudes in response to bigger than smaller disks, regardless of the task. In line with the ERP results, reaction times were faster and mean grip apertures were larger for the bigger objects. These findings demonstrate that size constancy for real objects placed at different distances occurs at the earliest cortical stages and that early visual processing does not change as a function of task demand.

Visual perception can learn from action. A study of cross-modal cue recruitment.

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Visual perception is not a stand-alone process. Pictorial awareness of the world we live in involves a multisensory process which integrates sound, proprioception, haptics and more.

The aim of this study was to demonstrate the flexibility of this system of integration by training perception to recruit novel sources of information that it initially deemed irrelevant.

We investigated the effects of conditioned movements on visual awareness in human subjects. To do this, we used an associative learning paradigm, linking action-related information to two ambiguous geometrical figures: a Necker Cube and a Lissajous sinusoidal pattern. Because the percept of these stimuli is inherently bistable, these two stimuli served as sensitive measures of perceptual adaptation under our classical conditioning paradigm.

We found that while traditionally vision has been described in the Gibsonian manner of perception-for-action, the reverse is also true.

Our findings suggest that the list of cues known to affect perception should be enlarged to include voluntary movement and more broadly, that perceptual processes are subject to novel, relatively arbitrary associative learning processes.

Lexical Access to Function Understanding is Influenced by the Objects Utilized for an Action

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As we go about our days, we interact with the objects around us. Anchor objects (e.g., a shower) have been shown to be important for visual search and scene conceptualization as they dictate the spatial layout of scenes and hold predictions about the presence and locations of local objects (the shampoo bottle or razor). However, the importance of anchor and local objects for our ability to understand the actions we can perform in a scene (the scene's functions or affordance) is yet to be explored. Many indoor scenes are designed to suit our action goals. As a result, scenes can be subdivided in action-relevant objects clusters ("phrases") that surround anchors. Do objects from different action-related phrases and scenes differentially influence the perception of affordance in scenes? Here, we used a lexical decision task (LDT) performed on action words to investigate how viewing objects co-activates action concepts. Two factors were manipulated: object type (anchor vs. local object) and the degree of relatedness to a target action (e.g., showering). That is, anchor and local objects could either be action related (shower/shampoo), action unrelated but from the same scene (toilet/toilet paper), or action unrelated and from a different scene (sofa/remote control). Reaction times were fastest when participants were primed with an action-related object and significantly slower when the priming object was action-unrelated or from a different scene, irrespective of object type (anchor vs. local). Our results imply that objects influence affordance perception and thus prime lexical access to action words, presumably since objects are spatially organized based on their functionality. We conclude that both anchor and local objects hold predictions about the actions we can perform in a scene, and they are activated automatically.

Adaptation of forearm orientation inhibited by visual information

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Higashiyama and Yamazaki (2022) have demonstrated that when the whole body is visually and/or kinesthetically inclined for adaptation for several minutes, the subjective horizontal is shifted to the adapting slant. In this study, we investigated perception and adaptation of the orientation of forearm when visual information is available or deprived. In Experiment 1, 20 blindfolded participants placed the right forehand for 90s on the board that was slanted at -30deg, 0deg, or 30deg in the median plane and then judged nine slants of the board around the adapting slant. In Experiment 2, different 20 participants did the same task in as Experiment 1, but during judgments, they did not wear a blindfold, looking around the laboratory and even at their own arms. In Experiments 3 and 4, the participants judged tilts of the board on which the forearms were placed in the same way as Experiments 1 and 2, respectively, except for superimposing the forehands on the board in the frontoparallel plane. The judgments for each adapting slope in each experiment were described as a linear function of sine of objective slant/tilt, and the subjective horizontal (SH) was then estimated from each function. For the slant judgments, the mean SHs were -12.6deg (-30deg), -2.7deg (0deg), and 5.0deg (30deg) for the blindfold condition and were -5.5deg (-30deg), -1.7deg (0deg), and 1.3deg (30deg) for the unblindfold condition (the angle in parenthesis represents the adapting slope). For the tilt judgments, the mean SHs were -7.3deg (-30deg), -0.3deg (0deg), and 7.8deg (30deg) for the blindfold condition and were -4.3deg (-30deg), 0.2deg (0deg), and 5.0deg (30deg) for the unblindfold condition. It was suggested that adaptation of forearm orientation, regardless of pitch or roll, is inhibited by visual information.

Assessment of biophilic design and impact on visual perception in patient rooms

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Designing healthcare facilities can be among the most demanding projects for architects and engineers. Providing a microbe and bacteria-free environment, using expensive mechanical equipment for the demanding tasks of sterilisation and ventilation, is prioritised. Architects and engineers often neglect the importance of providing pleasant and calming environments. The concept of biophilic design emphasises using design approaches to connect people with nature. Many studies indicate that implementing natural elements in interior spaces could improve the health and well-being of occupants by reducing stress and other physiological parameters. However, there is not much research on how biophilic design could be used as a design approach for patient rooms in healthcare facilities. In addition, most of the existing studies use qualitative methodologies to assess the impact on human psychology. Based on the existing research gaps, more research needs to be conducted using quantitative methods to define precisely how natural parameters (low vegetation, plants, trees) are related to mental health states. This study uses emerging technologies and methods such as virtual reality using eye-tracking for gaze direction measurements and wearable devices for physiological measurements. These methods provide the opportunity to quantify how different biophilic design strategies and approaches affect the mental health conditions such as stress or emotional affect in people. The focus will be on manipulating the wallpaper on the wall opposite the patient inside a patient room. Various images of natural elements will be used, such as photos of forests with trees and a river, trees in mountainous areas, Japanese gardens and more. An experiment will be carried out with participants who will use the VR headset showing the 3d models and collect heart rate data with wearable devices. This research aims to find which biophilic design strategies in hospital patient rooms show a higher positive psychological effect on people.

Obstacle Perception: A Heatmap-based Comparison of Human and Machine Alignment Focus Points

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Contemporary cities have been fragmented by a growing number of construction barriers and infrastructure damages that generate several problems that set pedestrian citizens at risk. The development of automated methods for detecting and recognizing people, barriers, and damages in visual data to create safe urban environments has been of particular concern to the research community in recent years. The use of deep learning algorithms is now the dominant approach in visual data analysis with very good results in a wide range of applications including obstacle detection. However, explaining learning models operation, remains a key challenge in gaining significant knowledge about how algorithms are trained. Post-hoc explainabity for deep learning models using heatmaps highlight the focal points in the input image that helped the generated model predict the output and could be a good start in that direction. In an effort to get an insight about the learning process in deep networks, we studied the similarities between heatmaps generated by deep learning algorithms trained to detect obstacles on sidewalks in images collected via a smartphone camera, and heatmaps generated by humans as they detect the corresponding obstacles on the same data. Heatmaps of 20 images related to 10 different obstacles were first generated by two state-of-the-art image recognition algorithms based on convolutional neural network and vision transform architectures, respectively. The image data set was then given to 35 users who were asked to locate the obstacles by generating the heatmaps with the help of an eye-tracker. The heatmaps were visually compared using a multi-grid approach, yielding interesting insights into human and machine obstacle perception, as well as the similarities between their focus points when detecting obstacles. Early results indicate that heatmaps created by humans resemble more closely to the ones generated by the vision transformer architecture.

Effects of accuracy demands and light level on hand movements in a grasp-and-place task

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While it has been shown that grasping kinematics are consistently affected by accuracy demands, it remains unclear if and how those accuracy-dependent changes are moderated by variations in visual uncertainty induced by changes in light levels. Here, participants (N=18) picked up empty or full water glasses in three different illumination conditions: 400 lux (photopic), 10 lux (mesopic), and 0.002 lux (scotopic) - and placed them on a slightly elevated coaster while their hand movements were tracked. Results showed that both grasping times and placing times increased in the scotopic condition but did not differ between the photopic and mesopic conditions. Furthermore, participants moved considerably slower when grasping and placing the full water glass as compared to the empty one. In contrast to our prediction that light levels may have larger effects on tasks with high accuracy demands, we did not observe an interaction effect between these variables. The slowing of the grasping movement for increased accuracy demands (i.e., full

glasses) was associated with a reduction in grasp point variability indicating a speed-accuracy trade-off. However, grasp-point variability remained similar in all illumination conditions. On the other hand, we found that the variability in placing the object on the coaster increased with decreasing light level indicating a decrease in placing- accuracy. Placing-accuracy was unaffected by accuracy demands. In summary, hand movements were slower and less accurate (i.e., more variable) in scotopic viewing conditions while there were no reliable changes between photopic and mesopic viewing conditions. This may explain why a previous study examining grasping across a range of medium and high light levels (50-750 lux) failed to observe any reliable effects of illumination on reach to grasp actions (Chiu et al., 2007, JAIHC).

Exploratory hand movements affect perceived material attributes in a dimension-specific way

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We have recently shown evidence for the multidimensionality of material softness perception in both semantic differentiation (adjective ratings), and hand movements during exploration (exploratory procedures, EPs, Dövencioğlu, et al., 2022). For visual stimuli, when both optical and mechanical cues are present, material judgments are strongly correlated with haptic judgments (Cavdan et al, 2020; Kılıç and Dövencioğlu, 2021). We have previously shown the complementary effect of mechanical cues for granular and fluid materials when they are shown in a video where dimension-specific EPs are also visible. In Experiment 1, to see the effect of dimension-specific EPs on perceived softness attributes, we used videos showing deformable (e.g., sponge-press), soft surface (e.g., fur - stroke), granular (e.g., sugar – run through fingers), and fluid (e.g., honey - pull) materials as congruent stimuli. For incongruent stimuli, we used EPs outside of the dimension such as a hand stroking pieces of sponge. Observers rated the same 8 materials in these videos according to 12 softness-related adjectives with congruent and incongruent EPs. Although we have seen an overall effect of EP congruency on perceived material attributes, the incongruent EPs did not have an effect on all materials. Contemplating that some EPs might still be informative even if they are associated with a different dimension, we ran Experiment 2 with the same congruent stimuli but stirring as the incongruent EP for all the materials. The role of EP congruency manifested itself in deformable and surface softness dimensions. Although the tendency for granular and fluid materials is in the expected direction, these results did not reach significant levels. Here we show that mechanical cues for materials differ in terms of their congruency of perceived softness dimension, and incongruent EPs should be carefully chosen as they can still be highly informative as mechanical cues for material perception.

Slightly perturbing the arm influences choices between multiple targets

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We constantly make choices about how to interact with objects in the environment. Such choices are largely based on visual information about the objects in question, including information about their positions relative to ourselves. Does this mean that we adjust our choices if our hand's position is perturbed? Sudden motion of structures near where we intend to intercept a target causes our hand to deviate from its path in the direction of the motion. We examined whether such a change in hand position can influence participants' choices between two options. The participants' task was to tap on as many sequentially presented targets as possible within 90 seconds. Sometime after a new target appeared, it split into two targets and participants had to choose which of them to tap. Shortly before the split, the background moved in a way that was expected to result in the hand moving slightly towards one of the two new targets. We examined whether such shifts influenced the choice between the two targets. The moving background influenced the hand movements in the expected manner: the hand moved in the direction of the motion. It also influenced the choice that participants made between the two targets: participants more frequently chose the target in the direction of the background motion. There was a positive correlation across participants between the magnitude of the response to background motion and the bias to choose the target in the direction of such motion. Thus, people consider sudden changes in their posture when choosing between different movement options.

Effects of dynamic alterations of depth cues during continuous dynamic interaction

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Depth perception is given by the integration of different cues. In particular, it is well known that texture and disparity contribute in different degrees to the perception of 3D orientation of a flat surface. This is done according to a weighting mechanism of the two cues, usually studied under static conditions. On this basis we wonder what happens in dynamic situations. In

particular what happens when one subject interacts with a cue while the other remains fixed. Is

that a bias on the perception? With the goal of investigating how interaction modulates perceptual processing, we developed a novel approach for delivering visual stimulation that could overcome the limit of traditional passive visualization. By leveraging graphics engines (e.g., Unity) and VR potentialities, we were able to design dynamic and complex visual stimulations in a straightforward approach. Changes in selected perceptual parameters are contingent on subject's actions. Specifically, we designed an experiment in which subject was presented with 3D oriented planar surfaces through a circular aperture. The surfaces were characterized by conflictual depth cues (disparity and texture) both in slant and tilt. The subject, bimanually acting on a wooden tablet hinged to a spherical joint, could interact with one of the two cues while the other remained fixed. We asked the subject to continuously rotate the tablet in order to align the perceived direction of depth gradient along diametrically opposing target tilts for 20s. We observed a systematic effect of the fixed cue on the subject motor behavior which suggests a contingent change of the perceived 3D orientation. We hypothesize that this effect could be due to a dynamic weighting of depth cues and that the proposed approach could contribute to a better understanding of how a dynamic interaction affects perceptual integration processes.

Variation in the location of the visual egocentre measured using a monocular and binocular sighting task

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The visual brain is responsible for determining the visual direction of objects in space relative to the viewer. It has been suggested that directional judgements are made relative to a single point, termed the visual egocentre, typically assumed to lie midway between the two eyes. Here we examined the variability in the measured egocentre location using both a monocular and a binocular sighting task, in a representative sample (N = 26) of adults with normal vision. Using a custom-built sighting apparatus, observers were asked to rotate the orientation of a rod in the horizontal plane until it pointed directly to the right eye, left eye or directly towards the observer during binocular viewing. Measurements were made along the horizontal azimuth for each of a range of eccentricities spanning ±52.5 deg. relative to the centre of the head. The mean point of intersection of the extensions of the rod's axis at each eccentricity, were used to derive estimates of the monocular visual directions and location of the binocular egocentre for each individual. Monocular measures give an estimate of the locations of the two eyes in the head which can be compared to the physical inter-ocular distance (IOD). Surprisingly, observers showed considerable variability in their monocular estimates, which were typically much larger than their IOD. For binocular viewing, the group egocentre was located on average 0.41 mm to the right of the median plane of the head and 24.05 mm behind the corneal plane, but there were considerable individual differences in its location. These findings confirm that the visual egocentre generally lies close to the median plane of the head. However, its position relative to the corneal plane is consistent with the axial length of the eye, compatible with a virtual cyclopean retina.

Manipulating attentional priority creates a trade-off between memory and sensory representations in human visual cortex

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People often remember visual information over brief delays while actively engaging with ongoing inputs from the surrounding visual environment. Depending on the situation, one might prioritize mnemonic contents (i.e. remembering details of a past event), or preferentially attend sensory inputs (i.e. watching traffic while crossing a street). Previous fMRI work has shown that early sensory regions can simultaneously represent both mnemonic and passively viewed sensory information. Here we test the limits of such simultaneity by manipulating attention towards sensory distractors during working memory. Participants (N=8) remembered the orientation of a briefly presented (500ms) target grating while a distractor grating (11s) was shown during the middle portion of a 15s delay. Subjects reported the target by rotating a dial (3s). Target and distractor orientations were selected randomly and independent of one another. Critically, the distractor grating was continuously contrast-reversing at 4Hz, and on every trial, there were 2–4 brief (250ms) and subtle changes in its contrast (decrease or increase) and its orientation (counter-clockwise or clockwise). In three randomly interleaved conditions, participants were cued to either ignore the distractor, detect distractor-contrast changes, or detect distractor-orientation changes. Despite sensory stimulation being matched in all three conditions, memory representations differed strongly throughout the visual hierarchy: Fidelity was highest when the distractor was ignored, intermediate when participants attended distractor-contrast, and virtually absent when participants attended distractor-orientation during the delay. This is juxtaposed with representations of the sensed distractor during the delay: Fidelity was highest when attending distractor-orientation, intermediate when attending distractor-contrast, and lowest when ignoring the distractor (even absent in parietal regions). These data imply that any trade-offs between memory and sensory representations are due to changes in attentional priority as opposed to just the presence or absence of concurrent input.

Self-initiation of attentional shift during visual search

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How to shift attention is usually instructed by an experimenter or a computer in laboratory experiments of attention studies. However, self-initiation of attention shift (or willed attention) should be investigated to understand how attention shifts in everyday life. We propose, here, a method to separate self-initiation shift of attention from attention shift following instructions. We developed a visual search experiment to realize conditions where attention shift by self-initiation and by cues can be compared.

There were four discs on a display with a rapid serial visual presentation (RSVP) of letter stimuli. The task was to identify the number of discs with target presentations in the RSVP sequence. For this purpose, participants searched targets to find whether targets were included in the sequence at each disc. Targets were 'As' among distractors, 'I', 'U', 'E', and 'O'. To perform the task, a participant shifted attention to another disc when they found a target in a sequence of a disc, which was currently being watched, or when he or she decided to check another disc because the disc did not seem the one with target presentations. Participants knew that the number of discs with targets could be either 0, 1, 2, 3, or 4. Attention shift was initiated by target detection (cued) in the first case, and by determination by him or herself (self-initiated) in the second case. Participants shifted gaze with attention and eye movements and electroencephalogram (EEG) were measured. The process of self-initiated attention was investigated by comparison of EEG signals during the fixation before the attention shift between cued and self-initiated attention shifts.

Results showed differences in spectrogram between before a self-determined and cued shifts of attention. Frontal theta shows significantly higher amplitude for self-initiated attention shift than cued attention shift as early as 2s before gaze shift.

Statistical Learning Alters the Latent Saliency of Attentional Priority Maps: As Revealed via Pinging and ERP's

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Exciting work in the working memory literature has demonstrated that hidden, or so-called 'latent', memory representations can be inferred through external perturbation. Here we explored whether the same technique can be used to visualise the landscape of spatial priority maps. It is generally assumed that statistical learning, for example about high probability target locations, affects weights within spatial priority maps. We hypothesised that while these maps may be hidden from techniques analysing elevated neural activity, they may be revealed after perturbing the visual system with visual noise. We sought to test this using the additional singleton paradigm to implicitly train participants to expect search targets to appear in certain locations in space. Then, in the intertrial period we occasionally presented high-contrast visual 'pings' similar to those used to reveal latent working memory content. Using multivariate pattern analysis on EEG data, we show robust anticipatory decoding of the high probability target location before stimulus onsets, but critically only on trials containing a 'ping' prior to search display onset. In addition to this 'ping' analysis, we also investigated proactive alpha lateralization and the N2pc response to targets at high- and low-probability locations. We found no evidence that alpha lateralization proceeded search onset, but that the N2pc evoked by targets was reliably larger at high-versus-low-probability locations in space. Together, these findings suggest that statistically learned spatial enhancement is mediated by changes of synaptic weights in the latent attentional priority map, resulting in the perception of targets at high-probability locations as more salient, and thus speeding attentional processing.

Object-based and salience-based attention development: evidence from free-viewing in infants and adults

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What factors drive infant and adult gaze behavior over complex

real-world scenes? In adults, attention selection is object-based; saccades are targeted towards objects, fixations fall around the center of objects, and are longer on objects than on the background. This study shows that infants (6 - 13-month-olds) also fixate on objects in the center and have longer fixation durations on objects than on the background.

Moreover, both infants and adults show an inverted optimal viewing position (IOVP) effect in which fixations closer to the center are longer than fixations in the periphery of the object. In addition, there are

preferred landing locations for saccades toward objects. Horizontal saccades typically land short of the object center while these undershoots are less prominent for the vertical directions. within-object saccades are targeted towards the center for both infants and adults.

Overall, we conclude that infants show similar tendencies as adults when fixating on objects. These results challenge the cognitive relevance theory which states that meaning and knowledge are the primary drivers of attention selection. As most objects are unfamiliar to infants the most natural conclusion seems that infant and adult object selection is driven by similar underlying low-level processes.

We discuss results in light of other developmental trends in infant free-viewing relating to horizontal and central biases as well as habituation. We bring together a number of phenomena that together form an interesting target for computational modeling and explore the basic tenets of such models.

Increasing saccadic vigor with reward: effects on main sequence, latency and presaccadic attention

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Saccades are ballistic rapid eye movements with highly stereotyped kinematics: their duration and peak velocity increase with increasing amplitude, a lawful relation known as the main sequence. Moreover, prior to saccade execution, visual sensitivity increases at the saccade target location, a phenomenon known as presaccadic attention.

Some recent studies suggest that the main sequence can be influenced by the subjective valence of saccade targets. Stimuli predicting a high probability of receiving a reward might increase saccade velocity and duration. Nonetheless, little is known about the spatial characteristics of these kinematic changes nor their influence on saccade-contingent mechanisms such as presaccadic attention. Here, we used a novel trial-based monetary reward paradigm to study the reward-related modifications of saccade kinematics and their potential impact on presaccadic attention.

In each trial, three peripheral locations (8 dva eccentric, random directions) contained flickering noise and a colored cue informing about the maximum possible gain in that trial (0c, 1c, or 10 cents). Subsequently, a saccade cue indicated which of these locations was the saccade target. At various intervals preceding the saccade (-200 to -50 ms), a Gabor patch was flashed for 50 ms at the saccade location. Participants saccaded to the target and were informed about the reward they received, which was contingent on movement speed. Finally, participants reported the orientation of the Gabor.

Reward prominently reduced saccade latencies, and caused an increase in saccade velocities and amplitude, weakly influencing the main sequence relation. Interestingly, reward effects were highly dependent on saccade direction with the highest reward modulations for vertical and oblique saccades. Finally, presaccadic attention as measured by the orientation discrimination performance was not significantly modulated by the reward manipulation. We are currently investigating these reward effects for a range of saccade amplitudes, using prolonged training to overcome the limitations of the present study.

Supported by European Research Council (grant No 865715) and Deutsche Forschungsgemeinschaft (grants RO 3579/8-1 and RO 3579/12-1) granted to MR.

Effect of Target-Distractor Similarity on Attentional Modulation in the Human Visual Cortex

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Visual stimuli compete with each other for cortical processing and attention biases this competition in favor of the attended stimulus. Does the relationship between the stimuli affect the strength of this attentional bias? Here, we used functional MRI to explore the effect of target-distractor similarity on attentional modulation in the human visual cortex using univariate and multivariate pattern analyses. Using stimuli from the four object categories of human bodies, cats, cars and houses, we investigated attentional effects in the primary visual area V1, the object-selective regions LO and pFs, the body-selective region EBA, and the scene-selective region PPA. We demonstrated that the strength of the attentional bias towards the target is not fixed but it gets weaker when the distractor is more similar to the target. Using simulations we provide evidence that these results can be explained by tuning sharpening, and not by an increase in the gain. Our findings provide a mechanistic explanation for previous behavioral results showing the effects of target-distractor similarity on attentional biases. These results further provide evidence suggesting the sharpening of tuning by object-based attention.

Perceptual coupling, not binocular rivalry, requires attention.

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Multistableperceptionoccurs when our sensory system is confronted with displays that can have two (or more) comparable

likely perceptual interpretations. When this happens, perceptual ambiguity is initially resolved in favor of one of the percepts but continuous viewing leads to semi-periodic switches of perception to the alternative (suppressed) perceptual interpretation. This phenomenon is observed for very different visual representations including ambiguous figures with bistable meaning, bistable static (Necker cube) or dynamic (kinetic-depth effect) depth, or binocular rivalry (BR) when dissimilar images are project to two eyes and information from one eye at a time is suppressed from consciousness. The latter display – binocular rivalry – stands apart from the rest of visual displays as it is unique in two features. First, it is the only kind of multistability that has been proven to require attention. Second, it is the only kind of multistable display that leads to piecemeal perception and prolonged transition phases. We argue that these two outstanding perceptual properties are not accidental and both stem from the nature of BR stimulus. Unlike other displays, even a small BR display is made up of multiple BR entities as the competition occurs at the level of a hypercolumn. Our unitary "clear" perception is a result of synchronization between individual patches of competition. We suggest that it is the synchronization a.k.a. perceptual coupling that requires attention, not binocular rivalry mechanisms themselves. We replicated an earlier experimental setup that demonstrated transient nature of perceptual coupling in kinetic-depth effect and combined it with an attention-demanding RSVP task used in BR experiments. Our preliminary results show that divided attention abolishes perceptual coupling leading to "mixed" perception of the two rotating spheres as in BR. This suggests that perceptual coupling, not BR mechanisms per se, depends on attention and is likely to rely on top-down mechanisms.

Dissociable roles of human frontal eye fields and early visual cortex in presaccadic attention – evidence from TMS

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Shortly before each saccadic eye movement, presaccadic attention improves visual sensitivity at the saccade target, at the expense of lowered sensitivity at non-target locations. Some behavioral and neural correlates of presaccadic attention are similar to those of covert attention – which likewise enhances sensitivity, but during fixation. Although presaccadic and covert attention are dissociable, this similarity has led to the debatable notion that the two processes are functionally equivalent and rely on the same neural circuitry. Indeed, oculomotor brain structures (e.g., FEF) are also modulated during covert attention – yet by distinct neuronal subpopulations. Micro-stimulation in non-human primates has shown that perceptual benefits of presaccadic attention rely on feedback from oculomotor structures to visual cortices. This feedback mechanism also seems plausible in humans, as both oculomotor and visual areas are active during human saccade planning. We investigated this hypothesis by applying TMS to frontal (rFEF+) or occipital (V1/V2) areas during saccade preparation. Participants received TMS near the occipital pole and marked their perceived phosphene. Subsequently, they performed saccades to their phosphene region or the opposite hemifield, while we applied double pulse sub-threshold occipital (V1/V2) or frontal (rFEF+) TMS at different times during saccade preparation. By simultaneously measuring perceptual performance, we show their causal and differential roles in contralateral presaccadic benefits at the saccade target and costs at non-targets: Whereas rFEF+ stimulation reduced presaccadic costs opposite of the saccade target (where presaccadic sensitivity is severely reduced) throughout saccade preparation, V1/V2 stimulation reduced presaccadic benefits, but only shortly before saccade onset, during the peak of presaccadic attention. Our results demonstrate a causal and differential role of occipital and frontal-oculomotor areas in presaccadic benefits and costs, provide evidence that presaccadic attention modulates perception through cortico-cortical feedback, and further dissociate presaccadic and covert attention.

The four factors of visual hypersensitivity: definition and measurement

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Increased subjective sensitivity to certain visual stimuli (e.g., repeating patterns, bright lights) is known to associate with several clinical conditions (e.g., migraine, synaesthesia, autism). Our recent research finds it is also common in the general population and has a clear impact on daily functioning. It is currently unknown to what extent the types of visual hypersensitivity experienced across these individuals are similar or different. Anecdotal reports suggest that people might be sensitive to different types of visual stimuli (e.g., to motion vs lights). To investigate these possible factors of visual hypersensitivity, we developed a novel questionnaire measure (the Cardiff Hypersensitivity Scale, CHYPS) informed by qualitative reports of visual sensitivity, its triggers, and corresponding coping mechanisms from a large general population sample (n = 765). Importantly, items focused on functional changes as a result of sensitivity (e.g., avoidance), rather than affective changes (e.g., dislike), which can be more difficult to calibrate across participants. Using this measure across three samples (n's > 350), we find four replicable factors of visual hypersensitivity supported by bifactor modelling. These are: brightness (e.g., sunlight), repeating patterns (e.g., stripes), strobing (e.g., light flashes), and intense visual environments (e.g., supermarkets). CHYPS and its subscales show very good reliability (α > .80, ω > .80) and

improved correlations with measures of visual discomfort (e.g., Pattern Glare) and clinical symptoms (e.g., migraine). In ongoing analyses, data from a large representative community sample (n > 2000) is being used to confirm this factor structure and assess their incidence across clinical groups. Further to identifying the factor structure of visual hypersensitivity, CHYPS can be used to help investigate underlying mechanisms which give rise to these differences in sensory experience.

Detecting and delineating visual field defects based on free-viewing in glaucoma

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Standard Automated Perimetry (SAP) is an important method to measure the visual field (VF). While for visually healthy adults it usually provides reliable results, for many patients it is tiring and difficult to perform.

In a previous simulation study we described a novel way of detecting and delineating simulated visual field defects from gaze tracked movie viewing. Our method compares a viewer's gaze to that of a group of control participants and derives predictions about the presence of VF defects. Based on this approach, we could distinguish between five archetypical simulated VF defects and no defect. The graphical depiction of the defect's shape and location matched the simulated VF defect shapes on a group level. In the present study, we assessed how well this new method is able to detect and delineate real VF defects.

To assess the performance of the method with VF defects, we applied it to data from 20 participants with glaucoma and 20 age-matched controls who each monocularly viewed a series of 1-minute movie clips while their gaze was being tracked.

Results showed that for most controls, our new analysis predicted an intact visual field, whereas defects were found in participants with glaucoma. For the participants with glaucoma, our predicted delineations of their VF defects did not compare well to those produced by SAP.

We conclude that free-viewing gaze behavior can be used towards detecting the presence of a VF defect. The observed discrepancy between our new method's delineation and SAP with real VF defects suggests that participants with glaucoma have learned to adapt their gaze behavior to maximally utilize their remaining visual field. Further work is needed to accurately delineate defects of clinical groups based on free-viewing.

Is there a common factor underlying visual abilities in patients with AMD?

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In vision, there is surprisingly very little evidence for common factors. Using large scale test batteries, most studies have found that there are only weak correlations between performance levels in different visual tests. Factor analysis confirmed these results. This means that a participant excelling in one test may rank lowest in another test. In aging research, cross-sectional studies have repeatedly found that older adults show deteriorated performance in most visual tests compared to young adults. However, within the older population, there is no evidence for a common factor underlying visual abilities. The same holds true for older adults with mild cognitive impairment, which shows only weak correlations between visual tests despite a strong association between visual and cognitive impairments. In this study, we investigated whether low-level ocular structural changes, such as age-related macular degeneration (AMD), affect visual abilities, i.e., whether a more advanced AMD stage is associated with lower visual tests performances. We tested a battery of visual tests in 50 AMD patients (13 early, 33 intermediate and 3 advanced AMD patients) and 50 controls. If AMD influence visual abilities homogenously, stronger between-tests correlations are expected in patients compared to controls. We found high intraclass test correlations, indicating good test re-test reliability (ICC31: [0.6-0.9]). AMD patients performed significantly worse in all but one visual test with large group effects (Cohen's d: [0.6-1.1]). All correlations, but one, were low. A high correlation was found between performance in visual acuity and contrast sensitivity tests, confirming previous results. Overall, however, there was no evidence for a stronger common factor underlying visual abilities in patients compared to controls. Since we have high test variance within the patient population, the reliability paradox cannot account for the results. Our findings are surprising and provoke the question, what we are measuring with commonly used visual tests.

Visual flow and complexity as triggers and rehabilitation stimuli for dizziness

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Visual flow and complex visual environments (e.g. supermarkets) can cause dizziness and instability in some people and is called visual vertigo. It is the leading symptom of Persistent Perceptual Postural Dizziness (PPPD), which is the most common functional diagnosis in tertiary neuro-otological clinics. Visual vertigo may be caused by an over-reliance on vision for balance and stability, relative to vestibular and proprioception. Exposing patients to complex visual flow can help reduce visual vertigo, potentially because it leads to "down-weighting" of visual information. We have built a web-based rehabilitation program (a game) for visual vertigo that: is flexible and allows graded control over visual stimulation as treatment progresses; includes virtually rendered real-life environments to reduce situational anxiety; and increases engagement and enjoyment of rehabilitation. In a feasibility trial, 126 participants reporting moderate to severe visual vertigo were assigned to either play the full game with visual flow (intervention) or play a version of the game with no visual flow (control) twice daily for 6 weeks. Participants completed a range of questionnaires on dizziness and anxiety symptoms, a daily diary, and chose between three virtual environments which varied in visual complexity (e.g. contrast, colour, orientation, and spatial frequency). The results of this feasibility trial are informing the design of a randomised control trial to test efficacy of the game for PPPD rehabilitation.

Long-term adaptation to a visual field defect improves functional vision: evidence from a continuous visual tracking task

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Accurate assessment of visual function is essential in ophthalmic care and rehabilitation. Conventional visual field (VF) tests primarily assess the severity of vision loss. However, having a VF defect for a long time could lead to more effective scanning behavior, which could improve the functional VF despite having no effect on the VF test outcome. Easy and intuitive ways to screen the functional VF could improve quality of care. Previously, we have shown that eye movements made during continuous stimulus tracking could potentially be used for such a tool. The aim of this study was to determine 1) if we can detect the presence and severity of VF defects while allowing scanning strategies and 2) if people adapt to their VF defect and how this affects their functional vision.

We evaluated tracking performance of 36 participants with glaucoma, having early, moderate, or severe glaucomatous damage and 36 healthy participants. Each healthy participant performed the task with the VF defect of a matched participant with glaucoma. All participants monocularly tracked a moving stimulus (Goldmann size-III) at three contrast levels (40%, 160%, 640%).

We found that the presence of either a real or simulated VF defect decreased tracking performance with the impact depending on severity of the defect. However, participants with glaucoma performed better than their matched control with a matching simulated VF defect. This difference increased for more severe VF defects and was more pronounced for higher contrasts.

Overall, the data show that a glaucomatous VF defect negatively affects tracking performance, but that those with glaucoma – who are used to the VF defect – learn to adapt to a certain degree for their defect, thereby improving their functional vision. Importantly, even in the presence of such adaptive strategies our continuous tracking approach can still detect the presence of a visual field defect.

Status of symmetry perception following prolonged visual deprivation

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The human visual system is exquisitely sensitive to bilateral symmetry. Although the roots of this proficiency are not definitively known, they may relate to the kinds of regularities present in ecologically important entities such as animals, faces, and plants. Even neonates are reported to exhibit sensitivity to symmetry, suggesting that visual experience may play only a limited, if any, role in the genesis of this ability. Against this backdrop, here we ask whether the perception of bilateral symmetry is resilient to severe restrictions of early visual experience. To this end, we worked with children who had early onset blindness and received sight surgeries at the age of several years.

We recruited two patient groups. The first (n = 11, mean age = 15.5y) had their sight surgeries two to four years prior to this study and therefore had had a significant period of visual experience post-surgery. The second group (n=5, mean age = 12.6y) was newly operated and had only had one month of visual experience. The performance of these two patient groups was compared with controls (n=6, mean age = 18.3y). Each of 50 stimulus images comprised ten colored discs arranged in a bilaterally symmetric or non-symmetric configuration. Our results reveal a significant compromise in symmetry-based classification across the patient groups, irrespective of the amount of visual experience they have had following surgery. Past work on symmetry perception in amblyopes is relevant for contextualizing these results. We find greater performance decrements than those of uniocular amblyopes. Working with visually naïve, bilaterally amblyopic participants allows us to probe symmetry perception while side-stepping the influence of the knowledge of the concept of visual symmetry. In summary, the data thus far indicate a profound role of early visual experience on symmetry perception and, perhaps, long-range visual analyses more broadly.

Autistic and schizotypal traits shape neural markers of predictive inference

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Humans develop different representations of the external world, even in the face of a common sensory experience. According to the Bayesian framework, these differentiations could be grounded on a different integration of prior knowledge with new information coming from the external world: some people are more prone to base their inferences on accumulated models and experiences, while others tend to rely more on input presented in the here and now.

In this research, we explored whether these different predictive styles could be directed by dispositional factors related to autistic and schizotypal traits, since recent advances in computational psychiatry suggest that autism (ASD) and schizophrenia (SSD) are characterized by an overweighting of sensory evidence vs. prior information, respectively.

To this end, we used a probabilistic detection task while simultaneously recording EEG to investigate whether neurobehavioral signatures related to predictive inference were diametrically shaped by ASD and SSD traits in the general population (n = 80).

We found that the position along the ASD-SSD continuum oriented the predictive strategies adopted by the individuals in perceptual decision-making. While proximity to the positive schizotypy pole was associated with the adoption of the predictive approach associated to the hyper-weighting of prior knowledge, proximity to ASD pole was related to strategies that favored sensory evidence in decision-making.

These results revealed that the weight assigned to prior knowledge is a marker of the ASD-SSD continuum, potentially useful for understanding the mechanisms contributing to the onset of symptoms observed in ASD and SSD and as a risk index useful to identify individuals at risk of developing mental disorders.

Prosopagnosia is highly comorbid with developmental coordination disorder (DCD).

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Our findings identify comorbid neurodevelopmental disorders experienced by people with developmental coordination disorder (DCD/dyspraxia), and specifically, the prevalence of prosopagnosia (a neurodevelopmental disorder associated with difficulties recognising familiar faces, e.g., friends or family) in this group. DCD is characterised by lifelong struggles with movement related tasks that most people take for granted, such as dressing, driving and handwriting. Previous studies highlighted that children with DCD experience problems recognising faces. Face processing difficulties are also prevalent in other co-occurring neurodevelopmental conditions, e.g., autism spectrum disorder (ASD) and dyslexia. We therefore investigated whether prosopagnosia is highly prevalent in adults with DCD by using a battery of online movement questionnaires (addressing both retrospective child and current adulthood difficulties) and facial identity processing tasks. Participants (DCD, n = 27, Control n = 37) were recruited via social media. Scores were analysed using t-tests and re-run controlling for ASD and dyslexia. People with DCD demonstrated significantly greater problems at both the initial perception stage of face processing and subsequent recall of unfamiliar and familiar face memory. The issues remained apparent even after excluding DCD cases with comorbid disorders associated with face recognition impairments. 56% of DCD participants met recently proposed formal diagnostic cut-offs for prosopagnosia. The findings of this study are the first to show the high prevalence of prosopagnosia in people with DCD, contribute to greater understanding of the condition.

When and why does eye behavior decouple from visual input during internally directed cognition?

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Previous research has shown that eye behavior becomes less determined by the visual input when attention is directed inward, e.g., when performing mental arithmetic or mind wandering. This phenomenon, referred to as perceptual decoupling, gained a lot of interest in research and application since it allows us to detect whether attention is currently focused inward or outward. However, it is still unclear under which conditions and why perceptual decoupling of eye behavior occurs.

In a series of 4 studies, we systematically investigate how task type (arithmetic, visuospatial) and workload of an internal task interfere with eye behavior that involves low (pupil light response, optokinetic nystagmus) or high levels of cognitive processing (continuous smooth pursuit, voluntary saccades). Each study investigates one specific eye behavior.

Results show that continuous smooth pursuit and voluntary saccades are especially prone to interference from internal tasks while pupil light response is not, suggesting that the involvement of higher-level cognitive processing in eye behavior plays a key role for perceptual decoupling. In the arithmetic task, higher workload leads to stronger impairment of eye behavior while in the visuospatial task, both low and high workload lead to strong impairment, suggesting distinctive roles of general and specific resource sharing between internal tasks and eye behavior for perceptual decoupling.

Further, detailed analyses of voluntary saccades suggest that the internal tasks specifically interfere with the execution but not planning of voluntary eye behavior, suggesting that eye movements associated with the internal tasks could play a role too.

Together, we shed new light on the specific conditions and processes underlying perceptual decoupling and further our understanding of this complex phenomenon.

Idiosyncratic eye-movement patterns affect behavioral and ERP correlates of face perception

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Faces all show the same basic facial features in the same general arrangement, but observers do not all adopt the same eye-movement patterns when looking at them. We conducted two experiments to investigate how face-viewing preferences affect face-sensitive event-related potentials (ERPs). In Experiment 1, participants were asked to complete a free eye-movement face identification block and two fixation number-controlled blocks in which the initial fixation location was restricted to the left eye or the nose. During this task, we used EEG to record participants' scalp electrical potentials. Participants were separated into two groups according to their eye movements in the free eye-movement block, with an upper-focused group who favored the eyes of faces, and a lower-focused group who favored the nose and mouth. In fixation number-controlled blocks, the upper-focused group performed better, fixated longer, and elicited a larger N170 amplitude for the eye-fixation condition than the nose-fixation condition. In contrast, the lower-focused group performed and fixated evenly and elicited comparable N170 amplitudes between fixation conditions. In addition, the P1 component was larger for the nose-fixation condition than the eye-fixation condition, and this difference was bigger for the lower-focused group than the upper-focused group. On the other hand, the P1 appeared to have no relation to behavioral performance. In Experiment 2, the behavioral results in Experiment 1 were replicated when fixation duration was controlled. These findings suggest that face identification is associated with an individual's favored looking pattern tuned by fixation location on a face, and the N170 provides an index of this identification performance.

Eye movements during 'everyday hallucinations': Scaffolded attention as a function of covert (rather than overt) attention

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Consider a regular grid pattern, such as on a piece of graph paper, or bathroom tiles. By definition, the grid has no structure beyond the individual squares — which is why it is all the more curious that many people *see* structure anyway: vertical and horizontal lines, block-letters and block-digits, even more abstract patterns. This is the phenomenon of scaffolded attention, in which people see more complex shapes and patterns on the grid — a phenomenon that does not occur when just staring at a blank page. This phenomenon has always been described in terms of the act of *seeing*, but just what exactly are the eyes doing during these 'everyday hallucinations' in the first place? Do eye movements reflect the patterns people report seeing (with the eyes effectively 'tracing' the shapes and patterns), or do these patterns arise independently of explicit intentional eye movements? The phenomenon of scaffolded attention has been explored directly only by several papers in the past, but eye movements in particular have never been tracked in previous work. Here, we explored the role of eye movements in people's experiences of 'spontaneous' scaffolded attention (when people were not told or asked about the phenomenon yet), and 'intentional' scaffolded attention (when people were asked to actively notice their experiences). Across experiments, visual hallucinations were accompanied by shorter and fewer saccades, and pupil size and dwell times predicted the onset and complexity of the hallucinations people experienced. But perhaps the key result was this: people experienced similar types of hallucinations in equal frequency even in the *absence* of eye movements — i.e., when the eyes were at fixation,

compared to when they were allowed to engage in free viewing. This suggests that everyday visual hallucinations from scaffolded attention may ultimately arise as a function of covert, rather than overt attention.

Tell me your point of view: Individual differences in gaze behavior predict individual differences in scene descriptions

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Individuals show consistent differences in the way they fixate complex scenes (e.g., de Haas et al., 2019), but it remains unclear whether individual gaze results in individual perception. Previous studies show that fixations predict object memory on the group level, but disregard individual differences. To address this gap, we conducted a study with 30 participants who viewed everyday scenes, while we recorded their gaze. After each scene presentation, we asked participants to describe the most relevant aspects of what they just saw. To compare interindividual differences in gaze behavior and scene descriptions, we computed pairwise observer similarities in object fixations and noun occurrences. We found a positive Pearson correlation ($r = .45$, $p < .001$) between the interindividual similarity of observers' gaze and the similarity if their scene descriptions. Further analysis revealed a lower but positive correlation ($r = .22$, $p < .001$) when dwell time differences were collapsed across semantic categories such as faces, implied motion, text, food, or touched objects. Interestingly, we found no correlation when comparing observers' scanpath similarity to description similarity ($r = .004$, $p = .942$). The correlation between the number of fixated objects and the number of named nouns ($r = .08$, $p < .001$), as well as the length of scene descriptions ($r = .14$, $p < .001$), indicated a positive trend that explorative eye movements lead to more detailed descriptions. Together, our results suggest that participants with similar fixation tendencies describe scenes more similarly. Additionally, gaze tendencies for specific object categories appear to play a significant role, which we will explore further. Moreover, we will investigate other fixation properties such as temporal dynamics and object detection or inspection.

Acknowledgement: This work was supported by European Research Council Starting Grant 852885 INDIVISUAL; BdH was further supported by Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) Project Nos. 222641018-SFB/TRR 135 TP C9 and HA 7574/5-1.

Grasping follows Weber's Law

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Weber's law is considered one of the most fundamental psychophysical principles. Yet, many studies reported that visually-guided grasping, a central and basic human ability, did not follow Weber's law – a surprising exception. We suggest that this conclusion arises from a methodological fallacy, and that grasping indeed follows Weber's law. The typical version of Weber's law states that the just-noticeable-difference (JND) in stimulus magnitude increases linearly with stimulus magnitude. However, typical grasping studies used the within-subject standard deviation (SD) of the grasping response instead of the traditionally used JND. We show that using the SD as a proxy to JND is only sensible when the measured response is a perfect, linear function of stimulus magnitude, which is not the case for grasping (the response is slightly bent for large objects). We provide a method to estimate the JND in grasping directly. We apply our method to fresh data, cross-validate our method by re-analysing data from our own previously published study, as well as two high-impact studies on this topic, including the first study to report that grasping did not obey Weber's law. We find Weber constants consistent with values reported in the literature for visual size estimation. Our conclusion that grasping does follow Weber's law is coherent with the near-omnipresence of Weber's law in different perceptual domains. Consequently, certain claims about perception-action dissociations based on absence of Weber's law in grasping will need to re-assessed. Also, the large body of literature investigating Weber's law in different boundary conditions of grasping, like pantomime grasping, grasping 2D objects, grasping in virtual reality etc., will need re-evaluation by appropriately estimating JNDs.

Active vision shapes ocular dominance

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Ocular dominance is a basic visual property that shows both developmental plasticity and short-term plasticity in adult humans, where 2h of monocular contrast-deprivation leads to a counterintuitive shift of ocular dominance in favor of the deprived eye. Here we asked whether the same plasticity is elicited by merely changing the utility of monocular signals for visuomotor control, without changing contrast.

Participants wore a VR set (head-fixed) with monocular screens connected with two cameras placed above each eye; these monitored the front space and sent their input to the corresponding eye, which participants used to perform a complex visuo-motor task (building blocks). After a familiarization phase, the input to the dominant eye was delayed by 333 ms, making it useless for visuomotor coordination. We found that, after 60 minutes of task performance, ocular dominance (quantified by binocular rivalry dynamics) was systematically shifted in favor of the delayed eye: a similar effect as that produced by contrast-deprivation. The shift was only observed when participants actively engaged in the visuomotor task, not when they passively watched a confederate perform the same task.

Based on these findings, we suggest that active vision is foundational to weighting sensory information, even at the level of simple visual processes as those setting ocular dominance.

Linking the space in visual and haptics

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Although most research on spatial relations focuses on visual perception, other senses, including touch, also contribute to spatial knowledge. The spatial perception in haptics and its interaction with visual perception is an underexplored field. In this study, our goal was to clarify the differences and similarities between visual and tactile perception of spatial relations as represented through language. We apply the framework presupposing that once an object (Figure / Central object (F)) is located or searched for, a reference object (Ground, G) is involved to establish the exact place of F (Talmy, 1975). Further, once the perceived space is represented linguistically, fine-grained and metric relations are transformed into categorical ones, frames of reference are selected, and spatial description is ordered in a coherent way (Newcombe & Huttenlocher, 2000). We used a production task in two sets of experiments with equivalent visual (n=104) and tactile (n=38) stimuli. Each stimulus contained two circles that were located in different topological (according to RCC; Randell et al, 1992) and geometrical (orientation, distance, axial information) configurations (n=14). Participants were asked where the marked circle in respect to the other circle is. The open answers were manually coded. The results show that although there were some fine-grained descriptions, the majority in both settings were categorical. Although similar linguistic descriptors were used, there were differences regarding frequencies (e.g., 'next to', 'under', inside'). Topological and geometric features matter but to a different degree in each setting.

This research is funded by the European Regional Development Fund for Post-doc grant agreement No 1.1.1.2/VIAA/3/19/506.

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Actions are characterised by 'canonical moments' in a sequence of movements

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Understanding what others are doing is an essential aspect of social cognition that depends on our ability to quickly recognize their actions. To effectively study action recognition we need to understand how actions are bounded, where they start and where they end. To this end we borrow a conceptual approach – the notion of 'canonicality' – introduced by Palmer and colleagues in their study of object recognition (Palmer, Rosch & Chase, 1981) and apply it to the study of action recognition. Using a set of 50 video clips sourced from stock photography sites, we have shown that many everyday actions - transitive and intransitive, social and non-social, and communicative gestures - are characterized by 'canonical moments' in a sequence of movements that are agreed by participants to 'best represent' the named action. Here we provide evidence for their privileged role in action recognition. In Experiment 1 (n = 102) we show that canonical moments from action sequences are more readily named as depicting specific actions than are non-canonical moments, with faster response times and higher sensitivity. In Experiment 2 (n = 95), which employed an old-new memory paradigm, participants memorized both canonical and non-canonical stills from action sequences and later showed significantly faster and more accurate performance for canonical images when discriminating targets from foils. We suggest that 'canonical moments' in action sequences are integral to action perception and representation because they convey maximal information about human actions.

Causal Effects of Pupil Size on Visual Processing

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The size of the eyes' pupils determines how much light enters the eye and also how well this light is focused. Through this route, pupil size shapes the earliest stages of visual processing. Yet causal effects of pupil size on vision are poorly understood and rarely studied. Here we report the effects of both experimentally induced and spontaneous changes in pupil size on visual processing as measured through EEG. We compare these to the effects of stimulus intensity and covert visual attention. Previous studies have shown that these factors all have comparable effects on some common measures of early visual processing, such as detection performance and steady-state visual evoked potentials; yet it is still unclear whether these are superficial similarities, or rather whether they reflect similar underlying processes. Using a mix of neural-network decoding, ERP analyses, and time-frequency analyses, we find that induced pupil size, spontaneous pupil size, stimulus intensity, and covert visual attention all affect EEG responses, mainly over occipital and parietal electrodes, but—crucially—that they do so in qualitatively different ways. Induced and spontaneous pupil-size changes mainly modulate activity patterns (but not overall power or intertrial coherence) in the high-frequency beta range; this may reflect a causal effect of pupil size on oculomotor activity and/ or visual processing. In addition, spontaneous (but not induced) pupil size tends to correlate negatively with alpha-band power and positively with intertrial coherence; this may reflect a non-causal relationship, mediated by arousal. Taken together, our findings suggest that pupil size has qualitatively different effects on visual processing from stimulus intensity and covert visual attention. This shows that pupil size causally affects visual processing, and provides concrete starting points for further study of this important yet understudied earliest stage of visual processing.

Stochastic resonance reflects decisional, not sensory, suboptimalities in human vision

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Stochastic resonance (SR) is a nonlinear phenomenon whereby the detectability of a signal is enhanced by the addition of small amounts of noise, resulting in non-monotonic behaviour of signal detectability as a function of signal-to-noise ratio (SNR). This behaviour is inconsistent with the principles of optimal statistical encoding, which predict that detectability should increase monotonically with stimulus SNR. In the context of human sensory processing, those principles are formalized by signal detection theory (SDT), the most established framework for modelling human detection of sensory signals.

Because SR has been reported for human behaviour, those measurements appear to undermine the applicability of SDT. However, existing measurements suffer from a number of potential confounds, such as criterion shifts and/or changes in spatial/temporal uncertainty, leaving open the possibility that SR-like measurements may not in fact indicate a failure of SDT, but rather a failure of the adopted experimental protocols to incorporate the principles of SDT.

We performed an extensive series of detection experiments specifically designed to gauge the potential contributions of confounding factors that may masquerade as SR. To study criterion bias, we tested both yes-no and 2AFC protocols. To study uncertainty, we performed both foveal and peripheral measurements, and designed our stimuli to minimize both spatial and temporal uncertainty. We also constructed a stimulus that explicitly addressed the role of uncertainty. Our measurements show that SR reflects suboptimal read-out of sensory signals at the decisional level, rather than sub-optimal encoding of the signals themselves. The main driving factor appears to be suboptimal placement of the decision criterion, in line with the tenets of SDT.

Gaze responses to visual perturbations during reaching

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When performing a goal-directed movement, such as reaching to hit a target, gaze is typically directed to the target in a proactive manner, before the hand arrives there. When the target changes position during the reaching movement, humans rapidly respond by adjusting their hand movement to still hit the target. However, less is known about how quickly humans adjust their gaze toward the new target position, and whether such gaze responses occur proactively. We asked participants to reach and hit as fast as possible a visual target presented centrally on a monitor. Shortly after the onset of the reaching movement, and in separate counterbalanced blocks, the target could jump to a new position in a predictable (100%), biased (80%), or unpredictable (50%) manner, requiring participants to adjust their movements accordingly. When the perturbation was predictable, eye movements toward the new target position were initiated earlier, often even before the perturbation occurred, demonstrating a proactive gaze response in

anticipation of the upcoming perturbation. These shorter eye movement latencies were not evident from the beginning of the respective block but developed as participants interacted with and learned the underlying statistical regularities. Hand movement corrections appear to occur earlier when the perturbation was predictable. However, directing gaze to the new target position earlier does not seem to affect the corrections of the reaching movement. These suggest that how quickly humans tailor their reaching movements to visual target perturbations is independent of whether the new target position is foveated earlier. We currently examine how such gaze and manual responses are modulated by healthy aging, where proactive control of movement may be more important to account for inherent sensorimotor delays.

A new object versus rejuvenated object in visual attentional selection

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A new onset object is predominantly encoded and consolidated in visual attentional processing. Once it is registered in memory storage, it becomes an "old" object that is not to be reprocessed. However, recent research reports that an existing, old object that has been viewed for some time is predominantly processed after a salient event (i.e., a transient brightening of the display), though the object has no onset signal. More specifically, participants quickly detected the target stimulus that appeared in the existing, old object (i.e., square outline) located on one side of the fixation after the salient event as compared to no event. This is because the salient event triggers a phasic activation in the locus coeruleus–norepinephrine neuromodulatory system, resulting in a reset of the neural networks mediating cognitive processing of the registered object. This network reset causes the registered old object to serve as a new object in visual processing (rejuvenation effect). The present study examined how new the rejuvenated object is in the attentional selection. First, we succeeded in replicating the rejuvenation effect (Experiments 1). Second, when the visual system was exposed to a new and old-but-rejuvenated objects simultaneously, it predominantly processed the new object (Experiment 2). That is, we obtained evidence that the onset of a new object overrides a rejuvenated object in the attentional selection. These results suggest that the salient event does not completely reset the neural network subserving the perception of the registered object. In other words, the salient event rejuvenates the existing object, but it does not renew it.

Effects of Interstimulus Competition on Attentional Target Selection in Conjunction Search

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Visual search for conjunctively defined targets is less efficient when search displays contain competing distractors with target-matching features. The mechanisms that are responsible for these competitive costs remain disputed. Here, we used the N2pc component as an electrophysiological marker of attentional target selection to investigate how the competition from partially matching (PM) distractors in the same display affects the allocation of attention to targets objects. Targets were defined by a conjunction of colour and shape (e.g., green circles), and PM distractors had one target defining feature (e.g., green squares or red circles). Some target-present displays contained no PM distractors. Others included either two or four PM distractors (one or two each on opposite sides). Target-present and target-absent RTs increased with the number of PM distractors in a display, indicating competition for attention. However, the early phase of target N2pc components was unaffected by the presence and number of PM distractors. This suggests that feature-based attentional biases were initially triggered in parallel and independently at different locations. In line with this interpretation, PM distractors in target-absent displays also triggered reliable early N2pc components. From about 220ms after display onset, competition from PM distractors started to affect target N2pc components. As the number of these distractors increased, N2pcs became smaller and were less precisely time-locked to display onset. RT-based median-split analyses revealed that these competitive effects on the amplitude and time course of N2pc components were more pronounced on trials where target-present responses were slow. These results are interpreted in the context of serial and parallel models of attentional target selection in visual search.

Behavioural and neural correlates of shifting within and between attentional domains

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During natural behaviour, our attention is in constant flux, rapidly transitioning between information available in the external environment and internal representations stored in memory. However, as past research has primarily investigated external and internal attention in isolation, relatively little is known regarding the dynamic interplay between these attentional domains. Here, we developed a combined perceptual and working-memory task in which participants could be presented with two consecutive cues, sequentially guiding attention between encoded contents, upcoming sensory information, or both.

Critically, the second cue could redirect attention to an item within the same domain as the first cue (internal-to-internal or external-to-external shift), or to an item in the alternative domain (external-to-internal or internal-to-external shift), allowing attentional shifts both within and between perception and memory to be systematically investigated. In a behavioural study, we observed larger costs when shifting attention between versus within domains. Next, we employed our design in a magnetoencephalography study, aiming to identify the neural signatures of within- and between-domain shifts via multivariate decoding. Besides being able to decode the current attentional domain, we could successfully predict whether participants were shifting within the same or between different domains. Importantly, shift types were similarly decodable regardless of whether shifting from internal attention to external attention or vice versa. In sum, our behavioural and neural results provide novel evidence regarding the commonalities and differences of prioritising information in perception and working memory as well as shifting within and between them.

Inhibition of salient but irrelevant distractor depends on search mode

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Attentional capture by salient but irrelevant distractor during visual search depends on search mode. Distractor captures attention in tasks that induce singleton detection strategy (targets defined as singleton, with characteristics inconsistent during the task). Distractor is inhibited or actively suppressed when target and distractor properties are known and consistent, allowing for a clearly defined target (and possibly distractor) template and inducing feature search mode.

In our experiment, the target was defined in the shape dimension, while distractors (present in 50% of trials) were salient in the task irrelevant dimension of color. Participants (74) were divided in three groups, so that we could separately test attentional capture by distractor when (1) target is a shape singleton with inconsistent and unpredictable characteristics among homogenous nontargets, (2) target is a shape singleton with consistent and predictable characteristics among homogenous nontargets and (3) in a classic feature search task in which target is in one specific predefined shape.

In both singleton search tasks the search RTs were slower when a salient distractor was present ($F(1, 48) = 11.35$, $p < .001$), with a larger effect of distractor presence in the task with unpredictable target ($F(1, 48) = 31.26$, $p < .001$) and there were more reproduced probe letters in location of salient versus average nonsalient distractor ($F(1, 48) = 45.21$, $p < .001$). In the feature search task, there was no effect of salient distractor presence on search RTs and no difference in the percentage of recalled probe letters in locations of salient and average nonsalient distractors.

Our results confirmed that the distractor is inhibited during feature search but not singleton search and also showed that in the task which allows for both strategies (singleton target and consistent characteristics) distractor inhibition is impaired and attention is captured in a bottom-up way.

Non-image forming vision as measured through ipRGC-mediated pupil constriction is not modulated by covert visual attention

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When exposed to light, the pupil constricts, whereas in darkness, the pupil dilates: this is the pupillary light response (PLR), which, for a long time, had been considered to be a reflex. The PLR is driven by all photoreceptors—rods, cones, and intrinsically photosensitive retinal ganglion cells (ipRGCs)—where rods and cones cause the pupil to immediately constrict in response to light, whereas ipRGCs cause the pupil to remain constricted for as long as light is on. Recent studies have shown that the initial PLR is modulated by covert attention; however, it remains unclear whether the same holds for the sustained PLR that is driven by ipRGCs. In our study, we investigated the effect of covert attention on the sustained PLR. To do so, we leveraged the fact that ipRGCs are predominantly responsive to blue light, causing the most prominent sustained constriction in response to blue light. We found that the pupil constricted more when covertly attending to bright as compared to dim stimuli (with the same color), an effect that emerged rapidly after stimulus onset, thus replicating the effect of covert attention on the initial PLR. However, we did not find any difference in pupil size when covertly attending to blue as compared to red stimuli (with the same luminosity), whereas we did observe this difference when participants directly looked at the same blue or red stimuli. This suggests that the sustained PLR is not modulated by covert attention. This finding implies that non-image forming vision, as measured through ipRGC-mediated pupil constriction, is not modulated by covert visual attention.

Drivers compensate for environmental complexity by attentional prioritization of safety-critical events

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Complex everyday activities such as driving involve parallel tasks including situation awareness, navigation, and interaction with other road users, so performance can be limited by high-level visual processing. It remains unclear how these limitations affect performance in naturalistic, dynamic settings where perceivers can draw on experience to strategically adapt attention to familiar forms of complexity. This research investigates change detection during driving simulation to test whether participants can effectively allocate attention to overcome environmental complexity.

Participants (N= 80) aged 23-45 years old, drove along an urban environment, with three levels of visuospatial complexity (low-medium-high) defined based on a cognitive model of visuospatial complexity. Participants were asked to detect changes in the behaviour of road users and changes in the properties of street objects. Half of the cases of behaviour changes created safety-critical situations in which the driver had to detect and interact with other roadside users to avoid collisions. We collected multimodal data including eye-tracking, egocentric view videos, head movements, driving behaviour (steering, braking), and detection button presses.

Visuospatial complexity substantially lessened change detection. However, participants effectively responded to this load by increasing their focus on safety-critical events. While detection performance for non-critical behaviour and property changes consistently decreased as visuospatial complexity increased, performance for safety-critical behaviour changes was less affected. Gaze analysis supports these results suggesting that in high-complexity environments participants avoided attentional lingering on low-priority events and reduced looked-but-failed-to-see errors.

We conclude that choices of attentional strategies by the drivers as a result of environmental complexity limited the effect of distraction, leading to better gaze control and detection performance for safety-critical situations. We discuss the implications of this research for the training and testing of driving skills as well as the development of autonomous systems and assistive technologies.

Cognitive Components of Small and Large-Scale Foraging Behaviour

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Search tasks vary in difficulty, which can encourage the spontaneous utilisation of specific search strategies relative to task demands. Recent research has suggested that search strategies (via target switches) are influenced by imposed time constraints, which puts into question whether this observed effect on target switching can also be applicable to other constraints which induce "voluntary" changes in search strategies. As "time" exhibits a significant effect on search behaviour within foraging and visual search literature, tasks which greatly differ by duration (environmental scale: 3D large vs 2D small) were utilised. We found that increasing the scale of environment (and thus time) induced higher mean target switches, mirroring the effect of imposing time constraints. The larger scaled environments likely elicited greater switches as a compensatory measure to reduce overall task duration, as this environment presented a larger time penalty for not switching compared to "small-scale" search, even at the expense of higher cognitive costs associated with actively maintaining multiple target templates. Further experiments identified "distance between stimuli" and "navigation speed" to be factors which influence search strategies, when measured in isolated 2D environments (without compound effects elicited by previous 3D-centric tasks). A follow-up study was then conducted to assess whether the perception of "distance" or "speed" was more influential pertaining to our switch-based search context, thus identifying which factor was more significantly connected to the searcher's perception of "search costs", which revealed that "distance" was more influential than "speed" (for target switching). Overall, this suggests that search constraints which are both passive (scale/size differences) and forceful (time-limits) yield significant effects on search strategies, and the distance between target stimuli influences search decisions (switching) to a greater extent than the speed of the searcher, with both current and past studies supporting the multiple-template hypothesis model.

Examining Attention Patterns in Image Classification Tasks: A Comparison between Neural Networks and Humans

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The human ability to create and learn new concepts is remarkable, as even a few examples are sufficient to identify common content for a novel concept. Effective categorization of objects is a critical cognitive ability for successful interaction with the world, and therefore has been extensively studied in artificial intelligence research. While neural networks are biologically inspired, and thus expected to perform similarly to humans in cognitive tasks, it is important to compare the strategies of artificial intelligence and humans to further constrain the development of intelligent systems. To compare categorization ability, we propose comparing attention patterns in an image classification task between a neural network and a human. Averaged heatmaps for each image were obtained, highlighting areas that a person or Vision Transformer attended to while solving the classification problem. Results suggest that the main mechanisms of categorization (separation of object from

background, attention to contrasting parts of the material) can be considered universal, while differences in strategies are associated with the peculiarity of holistic perception of the image and the importance of social stimuli in human life. These findings suggest similarity in the internal architecture of structures responsible for the categorization process, which can be used to support the universality of conceptualization processes.

Attentional effects on the P300 component of the event-related potential during fast visual stimulation

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Background. The P300 component of the event-related potential is a marker of high-level cognitive processing and thus has been proposed for 'cognitive' visual acuity estimation. For future application of the P300 in cases of functional vision loss or suspected malingering, it is crucial to consider attentional modulation of this endogenous component as a confounding factor.

Purpose. The aim of our study was to investigate attentional effects on the P300 with fast stimulation sequences for acuity testing.

Methods. Visual oddball sequences were used to elicit P300 responses in 25 visually normal participants using a 3x2x2 design (sequence type x stimulus type x attention). We used a conventional 'slow', a 'fast' and a 'fast steady-state' oddball sequence with either gratings or Landolt C optotypes as test stimuli. Four test stimulus sizes at different levels of visibility/recognizability (−0.15, +0.0, +0.15 and +0.3 log arcmin relative to the participant's threshold) were shown. Distractors were presented concurrently and also formed an (uncorrelated) oddball sequence. In separate blocks, either test stimuli or distractors were attended and responded to.

Results. On the group level, significant P300 responses were observed in all but one tested condition when comparing the mean amplitudes of the unrecognizable (−0.15 log arcmin) vs. easily recognizable (+0.3 log arcmin) sizes. In individual participants, as relevant for clinical applications, the results showed that both stimulus type and sequence type determine the susceptibility of the P300 to attentional diversion.

Conclusions. Although the results suggest an effect of attention on the P300 with both stimulus types and all stimulus sequences, attentional diversion does not systematically result in a complete suppression of the P300. The use of fast stimulation sequences for objective acuity estimation thus seems possible. However, further improvements concerning the resistance against attentional diversion will be beneficial.

Acknowledgements. This work was supported by the Deutsche Forschungsgemeinschaft (HE 2504/9-1, project 435838478).

Cross-modal synchrony aids multi-target search

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Recently, we explored the impact of target synchronization during human foraging (Makarov et al., 2023). In our original study, participants searched for multiple targets defined by orientation that also changed color either asynchronously or synchronously. There was a clear advantage for visual synchrony, which we attributed to enhanced grouping. Interestingly, there was no additional advantage when the color changes were accompanied by a non-spatial auditory cue, contrary to predictions from the "pip and pop" effect (van der Burg et al., 2008). Here, we further explore the relative effectiveness of visual and auditory cues, using a more difficult search task where the targets themselves were defined by synchrony. Displays consisted of 36 circles arranged in a 6×6 grid. A small dot moved around the circumference of each circle, changing position by increments of 30°, starting from a random location. Across trials, the rate of target rotation varied between 9 and 12 rpm. Importantly, the 12 target dots all changed position synchronously. An example of the target change was always provided in the upper-left element of the grid. Participants were required to select 6 additional targets using the mouse. The remaining 24 items were two distractor sets, either moving faster or slower than the targets by a fixed offset of 167 ms (10 refresh cycles). We compared a baseline visual-only condition to a visual-auditory condition, where target changes were accompanied by a beep. The results were very clear. For all 12 participants, trial completion times were significantly shorter in the visual-auditory (M = 27 s, SE = 1) than in the visual-only (M = 54 s, SE = 3.3) condition. As search remained extremely slow and effortful, it appears that the sound cue aided target detection decisions, but did not guide search.

Exploring Attentional Modulation Effects on the Perception of Complex Natural Stimuli: A Study on Human Faces

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Featural attention has been studied extensively in the context of simple stimulus dimensions. However, its effect on complex natural stimuli, such as human faces, remains largely unexplored. To investigate attentional modulation of human face processing, we systematically manipulate participants' attentional focus to different face feature dimensions in a controlled experimental setting. Subjects (n=131) are presented with pairs of human faces (n=64). Per experimental block, the first face of each pair must be classified based on either gender (male/female) or race (Asian/Caucasian). After the classification, which acts as attentional manipulation, participants rated the dissimilarity of the pair on a Likert scale from 1-4. Critically, the face pairs were generated to ensure only either gender- or race-discriminating features were modified between them, randomly drawn from four true dissimilarity levels. Successful attentional modulation would increase perceived dissimilarity if the dimension of attentional modulation is congruent with the dimension of face modification and decrease when incongruent. The results demonstrate that subjects perceived dissimilarity scales linearly with the true distance between the pair of face images in the model space. More interestingly, we find strong attentional effects precisely in the predicted direction. However, we also find unexpected interactions between race and gender in the observed attentional effects: similarity judgments of gender-modified Caucasian face pairs were more sensitive to attentional modulation compared to Asian pairs, while race-modified male face pairs were more sensitive to attentional modulation compared to female pairs. These findings suggest different dimensions of faces may be differentially sensitive to attentional modulation and highlight the importance of considering such interactions. More broadly, our results have implications for both the scientific study of featural attention in human processing of high-dimensional stimuli and also for understanding and mitigating biases in AI algorithms that are trained using human similarity judgments of such stimuli.

Changes in conflict-induced modulations of oblique effects in spatial attention

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Spatial attention is the ability of humans to selectively attend to stimuli that are relevant and to filter out irrelevant ones. This phenomenon can be demonstrated in the Eriksen-Flanker attentional task, whereby subjects need to discriminate target shapes surrounded by congruent or incongruent distractors. Previous studies have shown that processing conflicts of sensory information can be enhanced by the size of attentional focus. One possible modulation is the oblique effect, a perceptual effect when orientation discriminability is increased towards stimuli located in the cardinal directions. This oblique effect on attention can be explained by the intertwined nature of attention and perception. We hypothesised that task performance is modulated by not only distance but also differences in the combination of congruent and incongruent distractor conditions. In this study, 222 participants, ages 6 to 82, performed the modified spherical Erikson-Flanker task. Reaction times were then recorded to investigate changes in the flanker effect on visual attention. First, we compared the flanker effect with the adjacent (near) and the two next (far) positions of distractors to examine whether different degrees of congruent conditions can affect flanker performance and the size of attentional field. Secondly, we compared the scope of attentional focus in cardinal versus oblique locations. Overall, subjects performed fastest in congruent conditions. The effects of congruent and incongruent conditions in the far positions can affect reaction time when near distractors are congruent conditions. We found increased attention with targets located in the cardinal locations compared to off-side oblique, suggesting more precise attentional scopes at the cardinal locations. Main effects were seen in task conditions, orientations, and age groups, as well as an interaction between conditions and orientations. Our findings suggest that visual orientations are beneficial across spatial conflict resolution due to the narrowing of attentional receptive fields in cardinal degrees.

The influence of attention on visual asymmetries in the foveola

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Visual sensitivity in the foveola is not uniform at isoeccentric locations. However, contrary to what happens extrafoveally, the ability to discriminate fine detail is better in the upper, compared to the lower, visual field. Here we examined whether high-resolution control of attention in the foveola can compensate for these asymmetries in fine spatial discrimination by unevenly enhancing visual sensitivity across the foveola.

Participants (N = 5) performed a two-alternative forced-choice discrimination task while maintaining fixation on a central marker. Performance was tested at 4 cardinal locations, approximately 20 arcminutes from the preferred locus of fixation. High-precision eyetracking and gaze contingent display control

ensured that stimuli were presented at the desired locations. In half of the trials subjects were centrally cued to deploy their attention to one stimulus location where the target would briefly appear (100% cue validity). In the other half of the trials a neutral cue pointed in all four directions. Subjects were asked to determine the orientation of the target, a small (7x2 arcminutes) bar titled ±45 deg.

Consistent with our previous work, when subjects were not cued to attend to a specific location, visual discrimination was not uniform in the foveola. In the cued condition, the magnitude of the attentional effect was highest at locations characterized by a lower vs higher performance in the neutral condition (30±8 % vs 10±7 %,$p<0.001$). Importantly, even when the magnitude of the effect was low, performance in the cued condition was far from ceiling. As a result, when attention was engaged at a specific foveal location, the overall performance was more uniform across the foveola. These results suggest that, differently from what happens when attention is engaged extrafoveally, the control of fine scale attention in the foveola may be flexible enough to compensate for visual anisotropies.

Acknowledgements: This work was funded by NIH R01 EY029788-01 grant, NIH training grant T32EY007125 and NSF Award 1449828

The preparatory activation of attentional templates for the guidance of visual search and for the recognition of objects in non-search tasks

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The adaptive selectivity of visual processing is governed by representations of task-relevant object attributes, also known as attentional templates. Prior research has demonstrated that during visual search, templates involved in the guidance of attention are activated in a preparatory fashion, prior to the arrival of search displays. The present study investigated whether such proactive mechanisms are also triggered in non-search tasks, wherein attentional templates are only necessary for subsequent target recognition processes, and the guidance of attention towards targets amongst distractors is not required. Participants performed a search task for colour-defined targets amongst multiple distractors, and two non-search tasks where target stimuli appeared without competing distractors (a colour-based Go/Nogo task, and an orientation discrimination task, where the target colour was constant and could therefore be ignored). The preparatory activation of colour-selective templates was tracked by measuring N2pc components (a marker of attention allocation) to a series of seven task-irrelevant colour singleton probes displayed every 200ms within a fixed interval between successive target displays. As expected, N2pcs were triggered by target-colour probes in the search task, indicating that a corresponding guidance template was triggered proactively. Critically, clear probe N2pcs were also observed in the Go/Nogo task, and even in the discrimination task in an attenuated fashion. These findings demonstrate that the preparatory activation of feature-selective attentional task settings is not uniquely associated with the guidance of visual search, but is also present in other types of visual selection tasks where guidance is not required.

'Attentional transplants' cause recipients to like images similarly to donors: Evidence for inter-observer commonalities in how attention drives preferences

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When different people view a scene, they attend to different things, and these differences in attention in turn influence how much they like the scene they are viewing. Patterns of attention may be highly individually specific. However, the effects of these different patterns of attention on preferences may not be. Here we demonstrate this, using a new method of 'attentional transplants'. We show that, if an observer likes an image, it is possible to transplant their viewing pattern into another observer — and that this causes the recipient to like the image better, compared with transplanting the viewing pattern of a donor who disliked the image. In Experiment 1, 50 observers viewed images of landscapes by using their cursor to move a small circular viewing window around each image for three seconds. After viewing an image, they rated how much they liked it. For each image, we identified two 'attentional donors' — the Liked-it-Most observer who rated the image highest (normalized relative to their other image ratings) across observers, as well as the Liked-it-Least observer who rated the image lowest across observers. In Experiment 2, we recruited 100 new observers to serve as 'attentional recipients'. These observers viewed each image, but now passively, through a moving window which reproduced the viewing pattern of either the Experiment 1 observer who Liked it Most, or the observer who Liked it Least. Recipients gave substantially higher ratings to an image when they received the viewing pattern of the observer who Liked it Most, compared to when they received the viewing pattern of the observer who Liked it Least. From this, we conclude that individual differences in preferences for scenes are partly explained by differences in how we attend — but that there are important similarities across observers in how these patterns of attention then drive preferences.

A self-administered mobile assessment for Response Inhibition

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One of the cognitive functions often used for studying human attention is "Response Inhibition". Many researches have shown evidence of a high correlation between cognitive decline in aging and disinhibition behavior. The current study aimed to investigate the function but instead of using standardized cognitive tests to assess the behavior we used a self-administered Go-No/go task via a mobile application.

Seven hundred-fifty Thai elderly participants (91% female) were assessed using the Montreal Cognitive Assessment (MoCA) and the Clinical Dementia Rating (CDR®). Participants who scored less than 25 out of 30 on the MoCA and had a CDR total score of more than or equal to 0.5 were classified as mild cognitive impairment (MCI). Participants that did not meet this criteria were classified as the normal aging group. All included participants underwent a self-administered Go/No-go task. Accuracy (percentage of correct responses on both Go and No-Go trials), response time (RT) on the Go trials (milliseconds), and commission error rate (CO) (percentage of trials that participants elicited a 'Go' response on No-Go trials) were recorded.

The mean age of all participants was 66.79 years (SD = 7.18) and the majority of them (47%) were bachelor's degree graduates. The normal aging group consisted 596 participants (female: 73%, mean age: 67.7, SD = 6.86) and the MCI consisted 154 participants (female: 16.5%, mean age: 65.7, SD = 8.00). There was no significant difference in accuracy (normal aging 81.9%, MCI 18%, $p = 0.26$), RT ($p = 0.17$) or CO ($p = 0.21$) between the normal aging and MCI groups. Age of all participants showed a significant positive correlation with RT ($p < .001$) but, accuracy wasn't correlated with age (Spearman's rho = 0.07 , $p = 0.00$). A higher age was associated with lower commission error (Spearman's rho = -0.15, $p < .001$). The results also showed a significant difference in all measured variables (accuracy, RT, CO) between different education groups ($p<0.001$).

Geistesblitz: Repetition priming of indirect attentional sets

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During visual search for a unique target repeating the target features leads to faster search (repetition priming). But what happens if the features do not include the target and the target cue is negative, thus defined via exclusion? In other words, what happens if participants must figure out which stimuli are not the target to find the one that is? To address this, we employed two attentional sets for specifying targets: direct and indirect sets. In the former, the target is present on the screen, while in the latter, the target is cued via exclusion. We wanted to understand if not only the stimulus but also the way participants have to search for a target (the attentional set) is primed. We conducted three experiments based on the board game "Geistesblitz (Ghost Blitz)". In each trial, we presented several objects in different colours on the right side of the screen and a direct or indirect attentional set on the left side. Participants had to find and select the target on the right as fast as possible based on the cues in the attentional set. In the direct set, one of the objects matched exactly one of the potential targets while in indirect sets none of the objects matched exactly and participants had to find the one object that was not one of the objects in the set and not in one of the colours in the set. There was always only one correct target. We developed a series of ideal observer models that suggest repetition priming of the objects occurring independently for the two attentional sets. In addition, colour priming occurs independently of object repetition priming. Finally, we found only weak evidence for priming of the set itself with a differential time-penalty for identifying the set explaining response times equally well.

Size Modulation of Visual Attention Estimated by Steady State Visual Evoked Potential

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This study aimed to investigate how human spatial attention changes to cover different sizes of the visual field. Steady-State Visual Evoked Potentials (SSVEP) were measured in response to four different sizes of concentric rings flickering at different frequencies. Participants were instructed to attend to a particular size to detect a target number presented in a rapid serial visual presentation (RSVP) sequence at 4Hz. A trial lasted for four seconds during which EEG signals were recorded. The SSVEP amplitude as a function of attended size showed a maximum at the attended stimulus size, decreasing with the difference between the stimulus and the attended sizes. When the SSVEP amplitude was plotted as a function of relative size (the ratio of attended size to stimulus size), an inhibitory effect was found for stimulus close to the attended size. That is, there is reduction of SSVEP amplitude for the response to stimulus whose size is one step larger or one step smaller than the attended size. The results indicate that visual attention changes its size to

cover the area of the stimulus target, and that there are enhancement and inhibition effects in the size of visual attention. We also analyzed Event-Related Potential (ERP) to target presentations and found clear differences in performance between attended and unattended sizes. Unlike SSVEP results, however, there is no specific spatial structure, with larger responses to attended size and smaller and about the same responses to the remaining three sizes.

Facilitation effects and anisotropy of the attentional blink for targets presented in a rapid serial visual presentation sequence in the upper and lower visual fields.

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To understand the underlying mechanisms of the attentional blink (AB), we presented a rapid serial visual presentation (RSVP) series in each of the upper and lower visual fields and two target stimuli in each and/or only one of the series. We investigated factors that influence the detection frequency of the second target stimulus (T2) in particular. If an early, retinal location-specific mechanism plays an important role in the generation of the AB, we expected that the blink of attention would be more likely to occur when two target stimuli were presented in the same series than when targets were presented in different series in different visual field locations. However, the results of our experiments showed that the T2 was more likely to be missed when it was presented in each series of the upper and lower visual fields than when it was presented in the same series. The AB was more likely to occur when the T2 was presented in the lower visual field than when it was presented in the upper and lower fields. These trends did not vary significantly with the distance between the two series, and were only observed when the two target stimuli were presented in the upper and lower visual fields. The enhancement of the attentional blink by the separation of the target stimuli into two series did not occur when the series were separated into left and right. These results suggest that the attentional blink is not caused by an early retinal position-specific inhibitory mechanism, but by the processes controlling the allocation of attention to each of the upper and lower visual fields, and that there is a strong anisotropy between the upper and lower visual fields in this attention allocation process.

Attentional sustainability under different types of notifications

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Two experiments were conducted to investigate attentional sustainability in digital environment. The modified Bourdon test was performed in digital organizer interface. Participants had to memorize three words (for 5 seconds), and then find all slots containing the target words within 30 seconds. A notification appeared in the lower right corner of the screen at 13-17 seconds; the participant had to click on the notification to close and return to the task. Two factors were varied: the saturation of digital environment (with or without perceptual feedback) and the type of notifications. In saturated environment condition, a change in the color or state of an interface element appeared when it was hovered or clicked by the participant. In the unsaturated environment condition, no feedback was presented. Five types of notifications were used: pop-out, slow upper movement, reduction in transparency, an appearance in the center of the screen, followed by flickering. In the first experiment, participants were presented with various types of notifications under saturated and unsaturated environment. In the second experiment, the content of the notifications was additionally varied: absence, word distractor, and call to attention ("Be careful"). Accuracy and RT were measured.

In the first experiment, accuracy was higher under the saturated condition. The type of notification affected RT, but not accuracy. In the second experiment, no significant differences were found for accuracy and RT under saturated and unsaturated environment. The type of notification still had an effect on the RT, but not accuracy. There error rate was the highest, when the notification contained a word distractor. Thus, the presence of content in notifications appears to be a more significant factor than feedback or type of notification. Presumably, the content of notifications causes working memory interference, which increases the error rate.

Neural activities preceding self-initiated attention

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To understand the mechanism of attention control in daily life, we compared brain activities related two types of attention shifts. One is attention shift determined by will and the other is that determined by a cue. We conducted an experiment, in which participants selected the location and time of gaze shifts without restriction while he or she was asked to detect targets among distractors in a rapid serial visual presentation sequence at each of four locations. The timing of gaze shift was detected to analyze EEG signals before an attention shift. There was a control experiment where sound cue was used to indicate the time and location of attention shift. Criticality state was analyzed using EEG results for different brain areas to compare neural activities before self-initiated gaze shift and before instructed gaze shift by sound cues. We assume that the two

types of gaze shifts are based on self-initiated and cued attention shifts.

Criticality states of neural activities is one of possible indexes of the brain state in preparing the attention shift. Although neurons in different brain area exhibit various activities, it has been suggested that the multiscale brain activities follow the criticality theory. In this study, critical state was analyzed to investigate the possible mechanism related with self-initiated attentional shift, analyzing electroencephalogram data.

The results showed that, first, the critical state analysis showed a power-law distribution with an exponent between -1.0 and -1.5. Second, the results showed that the transmission efficiency showed strong correlation with power-law exponent, with an efficiency of about 0.8 under both conditions. The values of the two indexes are approximately the same as previous results of self-initiated attention shift without eye movements. The present results suggest that there is change in critical state in the global dynamics of brain activity related to self-initiated attention.

Temporal regularities can be used to dynamically prioritise attentional templates during visual search.

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During visual search, we guide our attention toward target-like items using internal representations known as attentional templates. Attentional templates have traditionally been studied using static visual search tasks. However, outside of the laboratory our world is dynamic, with perceptual information constantly changing. It is currently unclear whether we can use temporal regularities in our environment to dynamically prioritise attentional templates. We investigated this using a dynamic visual-search task where participants searched for two targets sharing no features. During each trial, targets and distractors (coloured shapes) appeared transiently at different times and locations. Each of the targets had a higher probability of appearing at one of two times during trials. The 'early' target most likely appeared at the earlier time, while the 'late' target most likely appeared at the later time. Distractors varied in whether they shared features (colour or shape) with the early target, the late target, or neither. We found that participants were significantly faster and more accurate in finding targets when they appeared at their expected time. For targets that appeared early, participants were significantly more likely, and significantly faster, to identify the early target than the late target. For targets that appeared late, participants were significantly more likely, though not significantly faster, to identify the late target than the early target. This is consistent with participants using the temporal regularities in the task to predict when each target would appear and, accordingly, dynamically guiding their attention more toward features of the most imminently anticipated target. Analyses of eye tracking measures provide further insight here, highlighting differences in the attentional capture of distractors with early-target versus late-target features at early versus late times during trials. This work highlights the flexibility of our attentional system and our ability to use temporal predictions to dynamically prioritise attentional templates.

Acknowledgements: Oxford Medical Sciences Studentship (EPSRC); NIHR Oxford Health BRC (NIHR203316); Wellcome Trust SIA (104571/Z/14/Z); The Wellcome Centre for Integrative Neuroimaging (203139/Z/16/Z).

Similarities and differences in sensory hypersensitivity across 10 clinical conditions

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Every day we live through a range of sensory experiences – some are positive (e.g. listening to relaxing music), some are more negative (e.g. unexpected loud noises). Everyone has a different, subjective experience of the sensory world, and some people seem to be more hypersensitive than others. Often sensory experiences are studied in relation to certain clinical conditions, such as autism or synaesthesia, and in relative isolation from one another. Very little research has explored differences in sensory experiences across conditions or how they vary naturally in the general population. We carried out an online survey where we asked 739 people to recount their sensory experiences in everyday life. We asked people to describe: their reactions to sensory stimuli (positive and negative), what impact they have, and how they cope with negative experiences. We found that sensory hypersensitivities were relatively similar across people reporting different mental, neurological, and neurodevelopmental conditions: auditory stimuli tended to produce the most negative experiences, followed by visual stimuli, and then other sensory modalities. There were some differences across conditions, for example, people with migraine tended to report that they were particularly hypersensitive to visual stimuli. Using a template thematic analysis, we constructed three themes describing the impact that sensory hypersensitivities have on everyday life: 1) they are effortful and exhausting, 2) they limit social and functional capabilities, and 3) they create challenges in personal relationships. Specific sensory triggers and soothers were also identified, which may be useful in informing adjustments to public spaces to better accommodate those with sensory hypersensitivity and improve wellbeing.

Visual fatigue and power spectral analysis of accommodative response in asymptomatic and symptomatic individuals

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To facilitate visual fatigue diagnostic, we aim to find an objective indicator based on frequency analysis of accommodative response. Twenty young adults (22.65 ± 2.13 years) equally divided in two subgroups identified by the 16-items Computer Visual Syndrome Questionnaire (asymptomatic: 3.00 ± 1.25; symptomatic: 11.80 ± 7.83) were compared before and after a visual task consisting in 17-minutes of binocular reading on a tablet at 3.33 D (0.30 m) with 5-minutes of noncongruent task at the middle while accommodative demand changes by ± 2.00 D every 2.5 s. Accommodative response was measured during the first and last minute of reading with PowerRef 3 (50 Hz) on both eyes and for five minutes before and after noncongruent task with WAM-5500 (5 Hz) on right eye. The mean power spectral density (D^2/Hz) was calculated by Fast Fourier Transforms for three frequency bandwidths (low: 0.10 – 0.60 Hz; middle: 0.61 – 0.99 Hz; high: 1.00 – 2.30 Hz). Results were analysed using a mixed ANOVA (3 frequencies x 2 periods x 2 subgroups x 2 instruments). The only significant difference was observed between instruments ($p < 0.001$) certainly due to sampling frequency and record duration differences between instruments. No significant interactions were observed between those factors for WAM-5500 or PowerRef 3. Another ANOVA (3 frequencies x 2 periods x 2 subgroups x 2 eyes) reveal no significant difference between periods ($p = 0.20$), subgroups ($p = 0.54$) or eyes with PowerRef 3 ($p = 0.09$). No significant correlation was observed between questionnaire scores and power spectral density changes between periods with WAM-5500 (mean $p = 0.24$) or PowerRef 3 (mean $p = 0.85$). Frequency analysis doesn't show any changes for different bandwidths among symptomatic or asymptomatic individuals after a visual demanding task. Frequency analysis seems not be a good predictor of visual fatigue.

Objectively impaired developmental prosopagnosia cases are excluded when using liberal cognitive task-based diagnostic criteria

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Developmental prosopagnosia is a neurodevelopmental disorder characterised by lifelong problems when recognising faces. Traditional approaches to diagnosing typically required cases to score below an ultra-conservative cut-off (i.e., - 2 SDs beyond a neurotypical norm) on two tests of face processing. However, this excludes up to 85% of self-identified cases, and has the potential to undermine all estimates of cognitive impairments and treatment efficacy in this group. To counter these issues, some researchers have suggested liberalising this cut-off to 1 SD below neurotypical norms on two face recognition tasks. Here I show such an approach will result in a sizeable proportion (38%) of all self-identified prosopagnosia cases being excluded from our work, despite their levels of prosopagnosia symptoms being highly abnormal. Moreover, when pooled together to increase power, these excluded cases displayed deficits in face perception, face memory, and holistic processing. Given that excluded cases report quantifiably abnormal levels of prosopagnosia symptoms, and objective deficits in face recognition, I reaffirm Burns and colleagues' (2022) suggestions that a diagnosis should be guided by a case's symptoms, and not their cognitive test results.

Age-effects on gaze and hand movement when intercepting moving targets

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Catching a rolling egg before it falls off the table requires precise, synchronized eye and hand movements while anticipating the egg's path. If this path is not predictable, one can track the egg to gather information about its future position and then shift the gaze and hand to the position where the egg can be successfully intercepted. Both eye and hand movements are subject to sensorimotor delays because they are based in part on sensory information obtained in the past. These sensorimotor delays may increase with age, requiring older adults to reduce sensory sampling and adjust their sensorimotor behavior accordingly. We examined how aging affects eye and hand movements when intercepting a moving target. Younger and older healthy adults were required to hit a target moving along a predictable or unpredictable path, with the exact hit area being either of low (i.e., a single disk) or high (i.e., a curved bar) spatial uncertainty. The current data reflect similar gaze behavior between predictable and unpredictable movement paths for both age groups. However, when the hit area was of low spatial uncertainty, participants fixated that hit area proactively, regardless of the target's path. These proactive gaze shifts were similar for both age groups. In addition, participants brought their hand earlier toward the disk than the arc hit area, but this was not affected by path predictability. Older adults brought their hand closer to the hit area earlier, but also less accurately than younger adults. In summary, gaze is proactively shifted

when continuous visual sampling is less important. Aging does not seem to be associated with stronger proactive gaze shifts, but rather with hand movements arriving earlier at the future interception area, which may compensate for sensorimotor delays in manual actions.

Sensory responsiveness, core features of autism and alexithymia

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Although noted in the earliest descriptions of autism, anomalous sensory processing – including hypersensitivity to lights, sounds and textures, hyposensitivity and sensory seeking - has only been included as a diagnostic criterion more recently (DSM V, 2013). As anomalous sensory processing is hypothesised to precipitate other features of autism during development, here we ask whether differences in sensory processing in autism are predictive of core symptomatology and of alexithymia, a common comorbidity in autism which may reflect impaired interoception. Parents of autistic children (n = 33, 22 males, 11 females, mean age 11.4 (SD 3.9) years) and parents of typically developing children who did not have a diagnosis of autism or other neurodevelopmental disorder (n = 28, 19 males, 9 females, mean age 9.9 (SD 3.5) years) completed four standardised scales, the Short Sensory Profile-2, the Social Responsiveness Scale-2, the Social Communication Questionnaire (SCQ), and the Children's Alexithymia Measure. Across all four scales children in the autism group showed, on average, higher scores than children in the typically developing group, with large effect sizes (Cohen's d = 2.19 for SSP2, 2.86 for SRS2, 2.32 for SCQ, and 1.31 for CAM). Using the sub-scales of the Short Sensory Profile-2 we further show that, for the autistic children but not for the typically developing children, sensory hyper-responsiveness is predictive of core features of autism, of alexithymia and of restrictive and repetitive behaviours after controlling for the other two predictor variables, hypo-responsiveness and sensory seeking. These results are discussed with reference to predictive coding accounts of autism.

Mechanisms underlying visual discomfort and implications for urban greening

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The visual system routinely processes a continuous stream of visual scenes. Some scenes, however, provoke visual stress, irrespective of what they represent and in the absence of motion or flashes, and to different degrees for different individuals. Growing evidence shows that all the bodily symptoms of visual stress, from discomfort to headache and even to seizures, involve an excessive neural response. Yet, we know little about the mechanisms that link image spatial content or observers' idiosyncrasies to the excessive neural activity responsible for visual discomfort.

Here, we computed the activity of a biologically based neurodynamic model of the early visual cortex including excitatory and inhibitory layers that implements contour integration when encoding images of two sets of urban scenes (N=74 in each) and abstract art (N= 50 in each). Confronting different principled metrics of model activity and observers' self-reported discomfort revealed three markers for uncomfortable visual scenes: greater overall activation, less sparse model response, and a more uneven distribution of model activity across spatial orientations. Combined, these markers explained more than 40% of the variance in judgments of urban scenes. Moreover, when the strength of inhibition was decreased in the model, simulating the lack of GABAergic inhibition hypothesised to underlie interindividual differences in susceptibility to visual stress, the three markers gradually moved towards values typically found in the response to uncomfortable stimuli.

Taken together, these results suggest that both differences between images and between observers rest on a single unifying mechanism whereby the neural machinery responsible for contour integration is rendered inefficient by image spatial content and/or individual hyperexcitability. We show how our analysis can inform town planners and architects towards the design of more restorative and inclusive urban environments, and briefly discuss how visual science should join other disciplines to unveil the multiple benefits of urban greening.

Are people with anxiety traits more field dependent?

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Anxiety is a common mental health problem, characterized by excessive worrying about changes in the environment and

being susceptible to environmental cues. The cognitive style, field independence and dependence, reflects the way individuals perceive and process information from the environment. An individual who uses internal cues to judge perceptual tasks is field independent, while using external cues is field dependent. Our study aimed to investigate whether individuals with trait anxiety exhibited field independence and further examine whether there were gender differences. Participants completed the Trait Anxiety Inventory and the Rod and Frame Test (RFT). They were separated into anxiety and control groups, according to anxiety scores. The RFT included two indicators: frame disturbance, which represents the interference of frame tilt on participants' judgment of rod verticality, and field independence level, which represents participants' judgment strategy. We found that the frame disturbance of the female controls was greater than that of the male controls and the female anxiety group. The field independence level of the female controls was higher than that of the male controls and the female anxiety group. These indicated that compared to males, females were more susceptible to the interference of tilted visual frames, but high-anxiety females showed lower field dependence, which was contrary to our initial hypothesis. To explore whether other personality traits would have an impact on the effect of field dependence, participants were invited to complete the Big Five Inventory. The results showed that participants' anxiety traits were positively correlated with conscientiousness. The conscientiousness scores of the high-anxiety female group were significantly higher than those of the female control group, while there was no difference in males. Therefore, it revealed that the female's field dependence was higher than that of the male. Females with anxiety traits would show lowered field dependence, partly because they had higher conscientiousness and placed higher demands on accuracy when performing the RFT.

What is the neurological condition opposite to visual agnosia?

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Prof. Semir Zeki has contributed substantially to our knowledge concerning the neural basis of color vision, but his claim (in "a century of cerebral achromatopsia", p.1765) that cortical achromatopsia and agnosia with intact color vision constitute two opposite neurological conditions does not appear neuroanatomically substantiated. As early in 1892, Salomon Eberhard Henschen already classified hemianopia (in which the visual consciousness for the affected visual field is lost) and agnosia (i.e., "Seelenblindkeit" as this condition was referred to at his time) are a pair of opposite neurological classes: The former is with lesion in the primary visual cortex (V1, or "calcarine cortex" as referred to at his time) and with largely intact pre-striate cortical areas, while the latter is just the reverse situation; furthermore, he used these two classes of neurological conditions as positive and negative cases to establish V1 as the "vision center" in the human brain. Here I run an analysis of the relevant cases presented by Henschen himself and several more visual disorder cases reported after Henschen. Some of these cases have clear information regarding the patients' brain lesions, available through either autopsy neuroanatomical analysis or PET scanning / fMRI imaging in living patients. Overall, this analysis indicates that (1) Henschen's characterization of hemianopia versus agnosia as two opposite neurological conditions is more appropriate than Zeki's view concerning cortical achromatopsia versus agnosia, in terms of the brain damage patterns associated with these neurological conditions; (2) V1 is indeed what Henschen states as the "vision center" in the sense that it is a neural substrate for a primary type of visual consciousness – namely, the sensation for light and colors. Presently, Henschen's conclusion about V1 has largely forgotten; but here I attempt to reinstate this conclusion with an analysis of a set of relevant neurological cases as well as from an associationism's point of view – a view summarized by James Clark Maxwell as "all vision is color vision".

Receptive fields modulations following optic neuritis

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Background: Optic neuritis, a demyelinating neuropathy commonly associated with unilateral transient vision loss. Along with spontaneous remyelination, cortical adaptation mechanisms have been suggested to take part in the visual recovery process. To further study this hypothesis, herein, we explore modulation of the visual-field representation during the first year following first-ever optic neuritis episode.

Methods: We used fMRI to scan eight optic neuritis patients and 10 sighted controls while they viewed drifting bar stimuli in three different viewing conditions: Binocular condition (both eyes were stimulated) and two monocular conditions (the dominant eye or the non-dominant eye for the controls and the fellow-eye or the affected-eye for the patients). During the monocular conditions, a patch was used to cover one eye. Population receptive field (pRF) modeling was applied to assess the part of the visual field represented by each voxel within the early cortical regions: V1, V2 and V3. A Two-way repeated ANOVA with ROI and viewing condition as within-subjects factors was applied for each group separately.

Results: In accordance with previous reports, in the control group, the average pRF-size in V3 was significantly larger than those in V1 and V2. This pattern was observed in all three viewing conditions with no significant difference between them.

However, in the ON group, this pattern was maintained in the binocular and the affected-eye, but not in the fellow-eye condition, mainly due to pRF-size decreasing in V2 and V3. Furthermore, comparing pRF size's monocular ratio, i.e., (Fellow-eye)/(Affected-eye) vs. (Dominant-eye)/(Non-Dominant eye) showed a significantly smaller value for patients than controls within V3, as a result of the difference between the two monocular conditions among the optic neuritis group.

Conclusions: We suggest that the different pRF pattern of the fellow-eye reflects an improved visual resolution in the extrastriate cortex as a part of a spatial adaptation.

The effects of contrast modulation on peripheral visual acuity

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When central visual function is lost, finding ways of maximising peripheral acuity becomes a priority. Previous work has shown that introducing contrast modulation may improve resolution of letter targets presented against a uniform luminance background. Here we characterise the effects of a broader range of temporal modulation on peripheral acuity in individuals with normal vision (N=11). Observers' peripheral acuity (10 degrees eccentricity in the right visual field) was measured for static (black or white) and contrast reversing (7.5 or 15Hz) Landolt C targets presented on either a uniform background, a static patterned background (1/f^2), or a dynamic version of the patterned background contrast-reversing at the same temporal frequencies used for the targets (90% contrast). Observers were required to judge the orientation of the target (4 alternatives). In each trial the target was presented for 600msec. To estimate thresholds, we used a staircase procedure varying target size, and fitted full psychometric functions to data aggregated over several blocks. We then used linear mixed models to predict the best fitted thresholds using target and background type, and the dynamic state of targets and backgrounds as independent variables. In line with previous results, acuity for contrast-reversing targets was found to be superior to static white targets presented on a uniform background. However, no significant advantage was found relative to performance with static black targets. Results from patterned background conditions were more robust, with acuity for contrast-reversing targets exceeding that for both forms of static target. An advantage was also obtained by contrast-reversing the background, provided that the target remained static. These data suggest that contrast modulation is particularly beneficial when it acts to promote segmentation of a target from a background with visible spatial structure.

Funding: The Macular Society Research Grant: 'Promoting functional vision through modern digital technology'

The phenomenology of face blindness: A case study of developmental prosopagnosia

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Developmental prosopagnosia is a neurodevelopmental condition that impairs an individual's ability to recognize faces. While previous research has explored the neuropsychological and neural basis of this condition, little is known about the experience of faces for individuals with developmental prosopagnosia.

In a case study of an individual with developmental prosopagnosia, we aimed to understand the experiential aspects of encountering the faces of others. Through a series of phenomenological, semi-structured interviews, the prosopagnosic experience was described. The interviews were analyzed using Amadeo Giorgi's descriptive phenomenological method.

The results shed light on the experiential structure of perceiving, recognizing and imagining faces for an individual with developmental prosopagnosia. The interviews allow for an analysis of these cognitive processes, which are shown to be deliberate rather than automatic; conscious rather than unconscious; and shifting rather than stable. While the informant initially reports a complete absence of visual imagery and a severely impaired face recognition ability, the interviews demonstrate that visualization and recognition is to some extent possible, albeit via alternative routes. The present study may provide an avenue for developing better models of face processing and better objective measures of face processing performance. Finally, it highlights the value of qualitative research output for the continuous evolution of quantitative science.

Visual impairments in schizophrenia and schizoaffective disorder

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Background: Increasing interest in visual disturbances in various psychiatric disorders is connected with the fact that they are a potential biomarker for objectification of a mental condition. The aim of the study was to investigate differences in visual information processing between individuals with schizophrenia,

patients with the schizoaffective disorder and healthy individuals, and to analyze the relationship between visual system characteristics and clinical factors.

Patients and methods: thirty-three patients with the schizophrenia, 13 patients with the schizoaffective disorder and 35 healthy subjects were included in the study. Contrast sensitivity characteristics were measured by computer visocontrastometry. We presented the Gabor elements with a spatial frequency: 0.4; 1.0; 3.0; 6.0 and 10.0 cycle/deg. The parameters of eye microtremor (amplitude and frequency of microoscillations) were recorded using an optical system providing high-frequency video recording.

Results: the study found that the visual system in schizophrenia is characterized by increased sensitivity in the low-frequency range. The visual system in patients with the schizoaffective disorder is characterized by a change sensitivity in the medium and high -frequency range. Patients with schizophrenia showed significant differences compared to healthy controls in the eye tremor frequency of 70-110 Hz. Patients with delusional symptoms differed from healthy controls in the amplitude of eye tremor in the frequency range from 40 to 110 Hz. In schizoaffective disorder, differences have been established in the tremor frequency range of 55-70 Hz.

Conclusions: We consider the data obtained as evidence of a different nature of the mismatch between the magno- and parvocellular systems in schizophrenia and schizoaffective disorder. We propose to consider the parameters of contrast sensitivity and tremor eye movements as biomarkers of psychotic conditions.

Supported by Russian Science Foundation (Project No. 22-18-00074)

Predictions of sensorimotor contingencies is altered in the broad autistic phenotype

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Visual processing is constantly interrupted by gaze shifts. When executing a saccade, the visual scene moves across the retina with high speed. The sensorimotor system must act against this self-produced stimulus to prevent the perception of disturbing motion for every saccade. We have recently demonstrated that at the time of saccade initiation, a prediction is made about the motion vectors that is contingent on the requested saccade size and that sensitivity for this motion vector is selectively reduced. Here, we wondered about motion omission in autism because difficulties in generating and updating predictions is a core symptom of ASD. We hypothesized motion omission magnitude might vary according to participants' autism symptom severity. We used a paradigm in which motion stimulation is restricted to the intra-saccadic period by presenting gratings that were drifting faster than the flicker fusion frequency. Participants, covering a wide range of autistic traits, were presented either gratings that mimicked the natural motion velocity for the corresponding saccade vector or gratings that moved at unnatural velocities (e.g. 100°/s). Participants had to judge the location of the grating, which was presented in the upper or the lower part of the visual field. Motion prediction sensitivities were reduced as a function of the autism severity. Moreover, when tested with an adaptation paradigm, participants with high autistic traits showed difficulties in the ability to predict the upcoming motion associated with the requested eye movement, resulting in less amount of adaptation probably reflecting inefficiencies in assigning weight to the predictive information.

Problems in effectively adapting to and calibrating against observed sensory evidence could lead to both hypersensitivities and hyposensitivities in perception, which can be very disturbing and stressful to autistic people. We conclude that oculomotor inflexibility might increase the perceptual overstimulation that is experienced in ASD.

Brain Indices of Visual Memory in Chronic Moderate-to-Severe TBI.

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Objectives: To explore the predictive value of the hippocampus and global brain volume indices on visual memory tasks in individuals with chronic moderate-to-severe traumatic brain injury (TBI).

Design: Inception cohort study.

Setting: The study took place at the Centre for Applied Neuroscience, University of Cyprus. Participants were recruited from the Intensive Care Unit of Nicosia General Hospital and the Melathron Agoniston EOKA, the only governmental rehabilitation centre.

Participants: The group with chronic TBI consisted of 91 individuals with a primary diagnosis of moderate-severe closed head injury (age range=18-64 years; education range=6-19 years; mean time since injury=5.16 years; sex: 82 males, 9 females).

Main Outcome Measures: Magnetic resonance imaging (MRI) T1 anatomical images were used to conduct volumetry, voxel-based morphometry (VBM) and regions-of-interest analyses using MATLAB, SPM12, and CAT12. Participants completed a comprehensive set of neuropsychological tests, including measures of visual memory i.e. the Visual Span and the Rey Complex Figure Test.

Results: Global volumetric indices (i.e. grey matter, cerebrospinal fluid) correlated with tasks of visual memory ($p<0.05$). In addition, both grey matter and cerebrospinal fluid volume

indices hold predictive value on visual memory performance ($p<0.05$).

Conclusion: These findings highlight the role of the hippocampus in visual memory in chronic moderate-to-severe TBI. Greater brain atrophy is associated with poorer performance in tasks of visual memory several years post-injury. Implications for rehabilitation will be discussed.

MRI Biomarkers of Posterior Cortical Atrophy: A Single-Case Study

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Posterior Cortical Atrophy (PCA) is a prevalent form of atypical Alzheimer's disease. However, there is no single test available for its diagnosis. To identify the pattern of associated biomarkers, we used a multimodal MRI approach and investigated structural and functional alterations in a 61-year-old male patient with left homonymous hemianopia, memory loss, cognitive decline, and behavioral changes in absence of retinal impairments or other medication conditions.

We extracted vertex-wise cortical thickness (CT), local gyrification index (GI), and gray/white matter contrast (GWC), from the patient and 50 age-matched healthy controls, as these measures are associated with cortical atrophy and cognitive decline. Additionally, we analyzed the proportion of active voxels in cortical regions to evaluate alterations in neural activity during visual stimulation. This multimodal approach allowed us to identify the pattern of MRI-based biomarkers that may aid in the diagnosis of PCA.

A within-subject comparison indicated that biomarkers were primarily affected in the right hemisphere, contralateral to the visual hemifield deficit. Additionally, a between-subjects comparison revealed that posterior brain regions were primarily impacted. We also found that reduction of cortical thickness was most prominent in ventral occipito-temporal regions, whereas a reduction in the local GI was concentrated in dorsal fronto-parietal regions. Examining the GWC, contrast was more reduced in posterior regions overall and less affected in anterior regions, consistent with PCA. Interestingly, activity in primary visual areas was relatively spared and reduction in functional activation was concentrated in subsequent visually responsive areas.

These findings shed light on MRI-based biomarkers that reflect the regionally specific alterations in PCA, and may have significant implications for the diagnosis and treatment of this disease.

Investigating the Link between Language and Scene Knowledge: Insights from Eye Movements in Children with and without Developmental Language Disorder

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Humans are constantly exposed to a framework of rules and develop expectations about their environment. These rules govern our interactions with the world, and we rely on them to navigate our surroundings. For instance, we expect a toothbrush to be in the bathroom, not in the kitchen. The processing of visual scenes and language might be governed by similar rules based on semantic and syntactic regularities and it has been suggested that there are common cognitive mechanisms underlying these processes. To further investigate the link between language and visual cognition, we recorded eye movements of 11 children (age range: 6;7- 10;4) with Developmental Language Disorder (DLD) who show difficulties in either syntactic or semantic aspects of language development and 11 children with typical language development (TLD) (age range: 5;5-10;4) . They performed both a free viewing task containing consistent, semantically inconsistent, and syntactically inconsistent objects and a search task containing objects either consistently or inconsistently placed in the scenes. Results from the free viewing task partly replicated the consistency effect found for adults: Both groups showed more and longer fixations over semantically inconsistent objects compared to consistent objects, but contrary to adults they showed no such consistency effect for syntactically inconsistent objects. In the search task, the consistency effect was diminished for children with DLD: Their RTs for finding the target objects was not affected by the violations in the scenes which might suggest that they do not benefit as much from scene knowledge as TLD children do. In summary, our preliminary results imply that 6-10 year old children show sensitivities for object-scene inconsistencies that vary with task and are modulated by language abilities.

Visual differentiation in dyslexic children: An eye-tracking study

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Developmental dyslexia is a specific learning disorder manifesting itself through reading difficulties (e.g., errors in spelling and letter decoding). Nowadays, a large amount of information is presented in a text form, which impedes further education of an individual. The origin of dyslexia is neurobiological, and several theories try to explain it. Some of these theories are closely related to overall visual perception (e.g., insufficient visual differentiation of objects and letters) and eye movements. Eye movements can be recorded with an eye-tracking device. For elementary school pupils, it is crucial to learn properly differentiate objects and letters which can improve further reading skills (i.e., proper letter differentiation) of dyslexic readers. In the Czech environment, visual differentiation is included in standardized diagnostics of dyslexia. The visual differentiation task consists of a set of different shapes with variable orientations and positions. However, eye movements are not recorded during the visual differentiation task when diagnosing dyslexia. The main aim of this paper is to present the preliminary results of the eye-tracking study focused on eye movement aspects of dyslexic children during visual differentiation task and discuss the specific eye movement patterns in the described task. In conclusion, eye movement analysis of visual differentiation task can bring new knowledge into the field of overall visual perception of an individual and subsequently, it may have considerable influence on pupils' school performance and further development.

Eye tracking paradigm to identify saccade, pupil, and blink abnormalities in neurodegeneration

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Rapid-eye movement (REM) sleep behavior disorder (RBD) is a sleep disorder that has been identified as the most specific and common prodromal stages of α-synucleinopathies (αSYN) such as Parkinson's disease (PD), dementia with Lewy bodies (DLB), and the sporadic disease multiple system atrophy (MSA). Within 10 to 20 years, up to 85% of RBD patients may progress to a neurodegenerative αSYN disease. Consequently, it is crucial to identify specific prodromal biomarkers in RBD patients to predict who is more prone to phenoconvert.

Patients with PD and MSA have been shown to have oculomotor and pupillomotor abnormalities in previous studies. Thus, we examined saccade, pupil, and blink behavior in 134 control subjects (CTRL), 39 RBD, 37 PD, and 15 MSA while they sat in front of a monitor in a dark room. We performed Interleaved pro-/anti- saccade task (IPAST) consisting of two different instructions: pro trials: looking directly toward a stimulus, anti trials: looking away from the stimulus that appeared 10° to the left or right of the fixation point. In order to monitor gaze location, pupil size, and blink rate, a video-based monocular eye tracker was used.

Our results showed that PD and MSA had more anti-saccade direction errors than CTRL and RBD. Saccade amplitude was reduced in PD and MSA compared to CTRL. In the fixation period, RBD and MSA showed a reduced blink rate but not PD. Pupil dilation response was smaller in RBD, PD, and MSA compared to CTRL. Comparing anti versus pro-saccade trials displayed larger pupil size in CTRL and RBD subjects but not in MSA and PD.

The RBD group showed altered blink and pupil behavior but not saccadic impairments compared to the CTRL. PD and MSA pupillary deficits were more severe than RBD. These differences could help in clinical diagnosis and in discovering new biomarkers in RBD. Future longitudinal studies are needed to determine the robustness of these oculomotor measures to identify prodromal □SYN.

Investigating Gaze Behavior among Older Adults with and without Mild Cognitive Impairment in a Naturalistic Task

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Major neurocognitive disorders, such as Alzheimer's disease (AD), are a leading cause of disability and dependency among the elderly. In terms of global cost estimation, the World Health Organization predicted that by 2030, treating patients with AD and other forms of acquired cognitive impairment will cost the healthcare system US$1.7 trillion. Therefore, the successful detection of early signs of major neurocognitive disorders is of great importance. Eye trackers shouldn't be overlooked as cost-effective and non-invasive tools that can help to expose cognitive disturbances. Despite noticeable individual differences, the human gaze provides sufficient parameters to formulate psychological laws. In particular, specific gaze metrics may reveal disruptions in the coordination of brain regions and differentiate between healthy and cognitively impaired individuals. Mild cognitive impairment (MCI), the 'transitional zone' between normal cognition and Alzheimer's disease (AD), became a novel topic in clinical research. Yet, few studies have investigated exploratory eye-movement behavior among older adults with MCI. Therefore, combining two decision-making paradigms and a recall task is proposed to study visual scanning patterns and information processing strategies among older adults with and without cognitive impairments. This ongoing research is hoped to elucidate the pathophysiology of information search processes among older adults with MCI. Since the next decade of translational clinical practices will likely witness gaze metrics as potential biomarkers, the proposed paradigm may provide

valuable information for improving the clinical diagnosis of MCI and early AD monitoring.

Different top-down modulation of prestimulus alpha power and frequency in Developmental Dyslexia

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Developmental Dyslexia is a neurodevelopmental disorder affecting reading ability despite normal education and intelligence. In search of its core deficits, dyslexia has been linked to perceptual and attentional impairments, affecting temporal processing in the visual and auditory domains. In the neurotypical population, studies have reported that differences in prestimulus theta (5-7 Hz), alpha (8-12 Hz) and low-beta (13-20 Hz) oscillations predict perceptual outcomes, suggesting that ongoing oscillations play a role in determining whether two subsequent stimuli will be integrated into one unitary object or not. In dyslexia, prestimulus oscillatory indices of anomalous temporal processing remain relatively unexplored. Here, we tested 26 adults with and 31 without dyslexia in a segregation/integration task, where two rapidly flashing displays were separated by an interstimulus interval of varying duration. Participants were presented with the same visual stimuli, but based on task instructions they were asked to either integrate or segregate the two displays in order to find, respectively, the missing or the 'odd' element. While participants with dyslexia performed equally well to controls in the temporal integration task, they performed worse in the segregation task. When examining the prestimulus period, the speed of Individual Alpha Frequency predicted temporal segregation performance in neurotypical controls, with slower alpha frequencies predicting better segregation ability; the same association was not observed in dyslexics. Conversely, participants with dyslexia showed an increased alpha power in the segregation as compared to the integration condition in left parieto-occipital channels. Taken together, these results confirm that prestimulus oscillations reflect top-down modulations that vary according to task demands, and advance a novel relationship between reduced visual temporal resolution in dyslexia and prestimulus oscillations in the alpha band. The increased prestimulus alpha power observed in DD possibly reflects increased cortical inhibition and weaker allocation of attentional resources when rapid parsing of visual input is required.

What can eye movements tell us about the visual fields in children?

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Purpose: The golden standard for examining visual field is standard automated perimetry (SAP). However, this requires gaze fixation and active participation which makes it challenging for children. Clinicians instead turn to other tests such as Goldmann kinetic perimetry, tangent screen perimetry or confrontational testing. These are however difficult to reproduce and can yield unreliable results. Eye movement based perimetry have been investigated in relation to specific diagnoses such as glaucoma but many of these methods has yet to be tested in pediatric patients.

Methods: Healthy children and children with known visual field defects age 4-12 was invited to participate. Testing included ophthalmological examination, OCT, fundus photo and perimetry using the Octopus 900. For children unable to cooperate to examination in Octopus 900 was tested using the Goldmann kinetic perimeter. Visual field was also tested using Bulbicam (Bulbitech AS), SONDA (Reperio B.V.) and a saccadic reaction time test (SRT; Reperio B.V.). The children were asked to rate the tests using a visual rating scale. The performances were also rated using the EBAR scoring system.

Results: Performance according to EBAR was higher for all eye tracking based options compared to Octopus 900. The visual rating scale also reflected this, clearly showing a preference for these more functional tests.

Conclusions: There is a need for new methods of examining visual fields in children as standard automated perimetry is difficult to perform. Eye tracking holds a promising potential as children generally prefer this over SAP.

Face Recognition and Reading in Congenital Achromatopsia

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Rod vision is characterized by low acuity, complete color blindness, and a foveal scotoma. How will people who have spent their whole visual lives with only rods solve high-level foveal visual tasks? Will they be able to holistically recognize faces?

How good will their reading skills be? CNGA-achromatopsia is a congenital hereditary disease in which cone dysfunction leads patients to have rod-driven vision only. When we tested normally-sighted controls on foveal tasks under scotopic (dark) conditions, where only rods are functioning, we found slower, but intact, processing compared to photopic (light) conditions. Reading was twice as slow, but accurate, with the same preferred landing positions close to the words' centers. Face recognition performance was slightly worse, but the face inversion effect was still pronounced, suggesting intact global perception. We plan to test adult achromatopsia patients on the same tasks, comparing their results with the scotopic results of healthy participants. If achromatopsia patients will read faster and recognize faces better than controls under scotopic conditions, it will suggest a different and optimized development of the rod-driven visual system due to congenital cone input deprivation. However, patients might read even slower than controls under scotopic conditions or might lack a face inversion effect. Such results would suggest that these functions rely on high-frequency intact visual priors established under photopic conditions, which enable the perceptual skills to develop and transfer to scotopic conditions. In summary, the results of this study will shed light on the magnitude of plasticity of the high-level visual system in the presence and absence of cone input.

Decentralized viewing behavior on facial photographs depicting Bell's palsy

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Bell's palsy is a facial paralysis in which patients are unable to move the mimetic muscles on one side of the face. This palsy manifests itself for example in drooping of the orbital eye region and the corner of the mouth and is, therefore, visually perceivable. For this reason, people might exhibit divergent viewing behavior when looking at faces of people with Bell's palsy. In an eye tracking study, we presented photographs of 40 patients with Bell's palsy and 44 healthy individuals to 19 participants and asked them to freely view the photographs for 5 seconds (condition 1) and to look for physical markers of the disease (condition 2). We hypothesized that due to the exaggerated asymmetry of facial features in Bell's palsy, participants look more frequently at the lateral parts of the face. Generally, fixation frequency in the orbital region, the center of the face and the nose was higher than for the mouth area. When comparing facial photographs of patients with those of healthy controls, fixation frequency shifts, from the center of the face and the nose to the corner of the mouth congruent with the affected side. A similar effect was detected for the left eyelid, whereas for the right eyelid, fixation frequency remained constant. Additionally, we investigated the viewing behavior for all photographs (healthy and with Bell's palsy), comparing conditions 1 and 2. In condition 2, we found less fixations on the center of the face and the nose and more fixations on the eyelids, but there was little to no effect on the corners of the mouth. Our findings suggest that people tend to look at the lateral parts of faces with Bell's palsy. Furthermore, by focusing more on orbital regions, they exhibit a different viewing behavior when trying to detect this disease.

Eye movements and gaze dynamics toward familiar and unfamiliar faces in congenital prosopagnosia

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Congenital prosopagnosia (CP) is a life-long impairment in face processing that occurs in the absence of any apparent brain damage. Previous eye movement studies revealed that individuals with CP explore faces differently than neurotypicals. These studies mainly focused on specific scanning patterns of single faces showing, for example, that CPs spent less time examining the inner features of faces compared to controls. Current research, however, lacks a broader understanding of how dynamics of gaze towards faces are modified in CP under more complex settings in relation to the number of simultaneously presented faces, the familiarity of the faces, task demands and the ecological validity of the stimuli.

In neurotypical population, these factors are strongly related to gaze dynamics towards faces. For example, when participants memorized four pictures of faces (one familiar and three unfamiliar faces), their gaze was initially directed toward the familiar face, followed by a strong avoidance from it. Another study used a visual search task to show that familiarity signals were sufficient to guide eye-movements towards the target, even when the specific target was unknown. Finally, when presented with images of social scenes that included faces, participants exhibited face preference that varied across individuals but was stable within individuals.

The goal of the current study was to exploit these findings in the neurotypical population to examine discrepancies in gaze behavior of faces among CP individuals. This was done by employing the three tasks described above and tracking eye-movements under more ecological conditions. We explored the similarities and differences between the ways CPs and controls deploy their gaze when familiar and unfamiliar faces are embedded within a wider context. These results shed light on the behavior of CPs in natural conditions and on the long standing debate regarding implicit processing of familiarity in general and particularly in CP.

Loughborough University Concussion IDentification (LUCID): concussion diagnosis using smartphone-based eye tracking

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Sports players are at risk of head injuries and potentially concussion in any contact sport. Existing practice for measuring concussion during sporting events is highly subjective. More objective measures of concussion which provide rapid results are required to establish whether a player is able to continue or needs to be removed from the game. Eye movement tasks are able to distinguish between healthy and unhealthy/abnormal patterns of eye movements. During a concussion, neural pathways are disrupted, leading to measurable deficits in attention. The current study measured baseline eye movements of rugby players at the beginning of the rugby season. During the season, should a rugby player experience a concussion during play, then eye movements were recorded again. Baseline eye movements and post-concussion eye movements were compared. Eye movements were recorded using a simple smooth pursuit task on both EyeLink and on an Android tablet device which recorded eye movements with its user-facing camera. It was hypothesised that by using our analysis technique, we could differentiate between baseline and post-concussion eye movements, but also, we could demonstrate that our Android tablet performed favourably when compared to the EyeLink. These results would therefore indicate the utility of a simple Android app which could be used at the side of a rugby pitch for diagnosing concussion should a player receive head trauma.

Unlocking crowding: the impact of global configurations and ensemble statistics

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In crowding, the recognition of a visual target deteriorates in the presence of nearby flankers. Like most other effects in spatial vision, crowding has been explained by local mechanisms, such as pooling and local inhibition between similar elements. However, these explanations fall short because crowding depends on the global configurations of all elements in the visual field. Adding flankers can even improve performance (uncrowding). Understanding these effects of global configuration is challenging because even slight configural changes can change crowding to uncrowding and vice versa. Here, we show that one does not need to know the specific configuration of flankers to determine crowding strength but only their ensemble statistics. Observers discriminated the offset of a vernier. When a single central square surrounded the vernier, crowding was strong. When the central square had the mean orientation of other squares added to the display, crowding was weak. This occurred even when none of the other squares had an orientation similar to the central square. We propose that ensemble statistics affect crowding strength by determining the grouping and segmentation of visual features in clutter.

Crowding: an optimizing phenomenon?

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Crowding traditionally has been conceived as a detrimental phenomenon to vision with a fixed and compulsory pooling of peripheral visual features. However in several perceptual phenomena (from serial dependence to multisensory integration) pooling is employed selectively and sparingly in order to improve perceptual functions, often in an Bayesian optimal fashion. To this aim we devised a novel crowding experiment in which flanker and target reliability is controlled for. We found that 1) flankers have greater effect when they have high reliability 2) when targets have great reliability they are weakly crowded 3) crowding is dictated by the similarity of target to the average of the

flankers. 4) when crowding operates, response uncertainty decreases. All this evidence conforms with rules of optimal integration and suggests that crowding is a multistage process aimed at improving target representation by borrowing information from similar and more reliable items present in the surround.

Dissociating Representation from Access in Multilevel Crowding

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Crowding is an impairment in recognizing objects surrounded by visual clutter and is arguably the most fundamental limit on conscious object recognition throughout most of the visual field. For the past several decades, visual crowding was assumed to occur at a single stage bottleneck stage, only between low-level features or object parts, thus dismantling or destroying object information. Here, I will outline a large and converging body of old and new evidence demonstrating that this assumption is false: crowding occurs at multiple stages of visual analysis, and information passes through crowding at each of these stages. For example, the interpretation of lighting direction functionally occurs before crowding between

orientation information, thus showing that crowded visual information is not irretrievably lost. This wide body of empirical evidence points to a seeming paradox in object recognition: crowding happens at multiple levels, which would seem to impair object recognition, and yet visual information at each of those levels is maintained intact and influences subsequent higher-level visual processing. Thus, while crowding impairs the access we have to visual information at many levels, it does not impair the representation of that information. I will propose that this body of results can be explained by a hierarchical sparse selection model of visual crowding, where crowding is not due to degraded visual representations in the brain, but to impoverished sampling or selection of those representations, which can happen at multiple levels. Crucially, this model posits that crowding occurs at multiple levels throughout the visual processing hierarchy (rather than at a single bottleneck), and it can capture the balancing act the visual system achieves between need for scrutiny, the cost of resolution, and the benefits of ensemble.

What drives the elevation of crowding in clinical disorders of vision?

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Crowding is the disruption to object recognition that occurs in clutter, a process that strongly limits peripheral vision and which becomes elevated in foveal/central vision in clinical disorders such as amblyopia ('lazy eye'). Is the process that drives crowded errors in peripheral vision the same that disrupts vision in clinical disorders? In peripheral vision, crowded errors are not random, but rather reflect the combined appearance of the target object and its surrounding flankers. 'Pooling' models attribute these errors to an unwanted combination of target and flanker signals. We have recently observed the same pattern of crowded errors in amblyopic children, suggesting a common mechanism for these forms of crowding. This pooling process is by no means fixed. In both peripheral vision and amblyopia, errors decrease with increasing dissimilarity between target-flanker elements (in e.g. orientation/colour), which pooling models capture by varying the weights with which target and flanker signals are combined. Differences emerge for the higher level selectivity of these errors, however.

In the periphery, top-down 'grouping' effects (such as 'uncrowding' by a row of identical flankers that differ from the target) can reduce the strength of crowding. We find that the same manipulations do not reduce crowding in the amblyopic fovea. Thus, although these forms of crowding likely share a common basis, their flexibility differs. While peripheral crowding provides a gist of the visual scene by pooling elements in a flexible manner, crowding in clinical vision involves both an increase in disruptiveness and fewer opportunities for its amelioration.

An enhanced Bouma model fits fifty people's visual crowding

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Crowding is the failure to recognize an object due to surrounding clutter. We quantify crowding by the crowding distance, the minimum spacing between a target object and flankers needed for recognition. To characterize the statistics of crowding, we measured crowding distance for both radial and tangential flankers in 50 observers at 12 locations: three eccentricities (0, 5, and 10 deg) along the four cardinal meridians. Each threshold was measured twice. We fit the well-known Bouma law — crowding distance grows linearly with radial eccentricity — to log crowding distance of the 50 participants, explaining 82% of the variance, cross-validated. We then fit an enhanced Bouma model, with factors for meridian, flanking direction, target kind, and observer, explaining 94% of the variance, again cross-validated. The enhanced model improves the fit in several ways. At a fixed eccentricity, crowding distance varies two-fold across meridians, observers and flanking direction. We also present a peeking model that allows the same Bouma law to fit two sets of spacing thresholds, one measured with unmonitored fixation and one with accurate fixation. The associations of crowding with auditory informational masking, reading difficulty and size of hV4 suggest that it might be a useful biomarker for development and cortical health. Favoring that use, it can be measured in two minutes with a standard deviation across observers that is three times larger than the standard deviation of test-retest.

Geometry of the neural representation of color

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The geometry that describes the relationship among colors remains stubbornly unsettled. We tackle the question by using multivariate analyses of measurements of brain activity obtained with magnetoencephalography. We first show that color can be decoded from MEG data. We next compare the similarity of the MEG responses to different colors to patterns in color naming and assess how these relationships change in time. The most prominent universal pattern of color naming is accounted for by the decoding results: the greater precision in naming warm colors compared to cool colors, evident by an interaction of hue and lightness. Moreover, the results show that hue and luminancecontrast polarity can be decoded across changes in the other feature, which is consistent with the existence of both common and separable neural mechanisms for hue and luminance contrast. The decoding time course is earlier and more

temporally precise for luminance polarity than hue, a result that does not depend on task, suggesting that luminance contrast is an updating signal that separates visual events. Meanwhile, crosstemporal generalization is slightly greater for representations of hue compared to luminance polarity, providing a neural correlate of the preeminence of hue in perceptual grouping and memory. Additional experiments showed that classifiers trained on responses to color words could decode color from data obtained using colored stimuli, but only at relatively long delays after stimulus onset. Taken together, the results uncover a dynamic geometry that provides neural correlates for color appearance and generates new hypotheses about the structure of color space.

Neurometric colour space decoded from EEG signals.

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To decode colour representations, researchers normally bin single EEG trials into folds and average them, prior to training the classifier using such averages. This is done due to the noisiness of single trials but it may have the unintended consequence that some of the information decoded by classifiers is the very same information described by the numerous past event-related potential (ERP) studies. We conducted a series of experiments to ascertain the factors that drive successful decoding from EEG and found the following:

(1) decoding of hue is superior from isoluminant colours, indicating that luminance signals mask some of the chromatic information in the signal; (2) the neurometric hue space is highly non-uniform and does not reflect hue distances represented by perceptually uniform colour spaces; (3) hues can be decoded more reliably within than between saturation levels, in line with the marked effect of contrast on EEG waveforms; (4) Patterns in the confusion matrix indicate that hues are 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), just like the ERPs on which they are based. Nevertheless, the points of maximal anisotropy in the neurometric colour space can be informative of the underlying representational mechanisms and should be the focus of future work.

Categorical Colour Geometry

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Ordinary language users group colours into categories that they refer to by a name e.g. pale green. Data on the colour categories of English speakers was collected using online crowd sourcing – 1,000 subjects produced 20,000 unconstrained names for 600 colour stimuli. From this data, using the framework of Information Geometry, a Riemannian metric was computed throughout the RGB cube. This is the first colour metric to have been computed from colour categorization data. In this categorical metric the distance between two close colours is determined by the difference in the distribution of names that the subject population applied to them. This contrasts with previous colour metrics which have been driven by stimulus discriminability, or acceptability of a colour match. The categorical metric is analysed and shown to be clearly different from discriminability-based metrics. Natural units of categorical length, area and volume are derived. These allow a count to be made of the number of categorically-distinct regions of categorically-similar colours that fit within colour space. Our analysis estimates that 27 such regions fit within the RGB cube, which agrees well with a previous estimate of 30 colours that can be identified by name by untrained subjects.

Color geometry and neural geometry

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Similarity between percepts is used to accomplish many everyday tasks, such as object identification, so similarity is widely used to construct geometrical spaces to represent stimulus qualities, but the intrinsic validity of similarity operations supporting a particular geometry is almost never tested. We use Varignon's Theorem to test the intrinsic geometry of color space with relative similarities equated by setting perceived midpoints between pairs of colors. For perceptual color space, we demonstrate that geometrical structure depends on the mental representation used in judging similarity: No structure was discernible unless observers were instructed to use an opponent-color representation, which resulted in an affine geometry. We show that this affine space is invariant to changes in adaptation. Similarities based on a conceptual space of complementary colors thus power a geometric coordinate system. An affine geometry implies that similarity can be judged within straight lines and across parallel lines, and its neural coding could involve ratios of responses. The midpoint measurements deviate significantly from midpoints in the extensively used "uniform" color spaces CIELAB and CIELUV, showing that these spaces do not provide adequate metric representation of perceived colors. Colors are decoded from responses of narrowly tuned cells in Inferotemporal cortex, clustered by color preference. We present models that test whether this anatomical

geometry can support the empirical perceptual geometries through response similarity.

Our paradigm can test the intrinsic geometrical assumptions underlying neural representation space for many perceptual

modalities, and for the extrinsic perceptual geometry of the space of physical stimuli.

The non-Riemannian nature of perceptual color space.

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The scientific community generally agrees on the theory, introduced by Riemann and furthered by Helmholtz and Schrodinger, that perceived color space is not Euclidean but rather, a three-dimensional Riemannian space. We show that the principle of diminishing returns applies to human color perception. This means that large color differences cannot be derived by adding a series of small steps, and therefore, perceptual color space cannot be described by a Riemannian geometry. This finding is inconsistent with the current approaches to modeling perceptual color space. Therefore, the assumed shape of color space requires a paradigm shift. Consequences of this apply to color metrics that are currently used in image and video processing, color mapping, and the paint and textile industries. These metrics are valid only for small differences. Rethinking them outside of a Riemannian setting could provide a path to extending them to large differences. This finding further hints at the existence of a second-order Weber–Fechner law describing perceived differences.

Effects of light enhancement at 585nm wavelength on beauty reduction

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We investigated the effects of illumination with an enhanced light with wavelengths of approximately 585 nm on impressions of colors. The author has been investigating the effects of wearing special glasses (NeoContrast, Mitsui Chemicals) that attenuate light with wavelengths of 585 nm on colors. Our previous study found that these glasses made a variety of chromatic colors more vivid and beautiful (Nishikawa & Kitaoka, 2022). However, the colorimetric results only showed that the hue of many colors changed when light with wavelengths of 585 nm were attenuated. It is unclear why participants evaluated the colors as appearing more vivid. Therefore, to further investigate the effect of light with wavelengths of 585 nm, we conducted preliminary research on impressions of colors when light wavelengths of 585 nm was enhanced and to compare them with the effects of other light wavelengths. Two adults (female aged 27 years, male aged 61 years) observed a color checker chart (X-rite) under five lighting conditions (standard illuminant D65, D65 with an enhanced light with wavelengths of 420, 505, 585 and 660 nm). The results demonstrated that the beauty and vividness of chromatic colors changed marginally under illumination with an enhanced light with wavelengths of 420 and 660 nm compared to D65. However, it was suggested that the beauty and vividness of chromatic colors was greatly reduced under illumination with an enhanced light with wavelengths of 585 and 505 nm compared to D65 and illumination with an enhanced light with wavelengths of 420 and 660 nm. Specific light wavelengths, including 585 nm, may have the effect of making colors subjectively appear dirty, dull, and unpleasant.

Evaluation of classic colour constancy algorithms on spectrally rendered ground-truth

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The small number of available spectral images imposes a significant limitation to colour science. We used computer graphics techniques to spectrally render naturalistic images, used to investigate the performance of three classic colour constancy algorithms: 1) grey-world, 2) white-patch, 3) grey-edge. Rather than comparing the illuminant estimated by the algorithms with the one inferred from a white surface embedded in each scene, we evaluated existing colour-constancy algorithms based on the spectral images. For each of two indoor settings, we randomized the point of view of the virtual observer and the spectral reflectance of the surfaces, for a total of 50 random scenes per setting. We sampled random reflectances from a compact statistical model obtained by applying a Principal Component Analysis to spectral reflectance measures. We rendered each of these random scenes under 5 different illuminants, linearly spaced along the daylight locus, from blue (CIE x=0.2, y=0.18) to yellow (CIE x=0.6, y=0.37), for a total of 500 scenes. We evaluated the performances ofthe different algorithms by computing the angular error between 1) the ground-truth illuminant and the estimated illuminants, 2) the rgb colour of the pixels of each scene rendered under the equal-energy illuminant E and the colour of the pixels rendered under the other illuminants. We found that differences in performance between algorithms are massively reduced when evaluated on the whole scene rather than on the illuminated estimates. In particular, when using the white-patch or the grey-edge algorithms, the angular errors are respectively 89% and 87% then the grey-world algorithm one. Crucially, when we only considered the estimated illuminants, the angular error obtained with the white-patch or the grey-edge algorithms is much less (1% and 52%). Our, results highlight the importance of spectral ground-truth for colour constancy research, as well as the potential contribution of computer graphics to colour science.

Colour can be decoded from MEG frequency power

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Colour is an indispensable quality of our visual experiences. While colour representation is relatively well understood in early visual pathways, we do not know as much about how different colours are encoded in the brain. Previous studies have investigated cortical colour representation by decoding colour from EEG or MEG time series data, which are limited by their relatively low signal-to-noise ratio and dependency on precise stimulus onsets. We have instead used frequency power spectra from an openly available MEG dataset obtained by Rosenthal et al. (2021, Current Biology, 31(3), 515-526). Our preliminary results show that support vector machine classifiers can be trained to decode colours presented on single trials with high accuracy from frequency power spectra. Further results from different classifier approaches have the potential to reveal spectral power markers for the perception of different colours, at least within individuals. This could have important implications for the neural basis of colour perception in terms of how subjective colour experiences might arise at cortical levels. Our results can also provide promising avenues for applications in, for example, brain-computer interfaces for participants with reduced mobility, or the induction of colour percepts without real stimuli.

The work was funded by the ERC grant 949242 COLOURCODE to JB.

Skin colour discrimination sensitivity is not predicted by haemoglobin oxygen saturation of skin

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Background. Skin reflectance can be modulated along two dimensions by haemoglobin by varying the haemoglobin oxygen saturation or the haemoglobin skin concentration. Changes in haemoglobin oxygen saturation leads to specific changes in the reflectance spectra (a 'W' spectral signature; Changizi et al. , 2006, Biol Lett. 2, 217) and is associated with a colour shift towards red. Changizi et al. argue that human vision is adapted to theses skin colour changes in two ways: (1) The troughs of the 'W' spectral signature are aligned with the peak sensitivities of the Long-wavelength- (L cones) and middle-wavelength-sensitive cones (M cones), and (2) human observers should be maximally sensitive to colour changes brought about by the oxygen saturation of haemoglobin.

Methods. We first analysed the local minima of 2250 skin spectra (250 observers; 9 different facial locations). Secondly, we conducted a psychophysical discrimination experiment with calibrated skin images, skin-like images and uniform patches, rendered under different illumination conditions. Discrimination thresholds were obtained in 14 different colour directions including the direction associated with haemoglobin oxygenation. To determine the direction of highest discrimination sensitivity, ellipses were fitted in a 3D cone-opponent colour space (L/(L+M); S/(L+M); luminance).

Results (1) The troughs of the 'W' feature are present at about 542nm and 572nm in virtually all facial skin spectra, which is in good agreement with the peak sensitivities of the L and M cones, located at 570 and 543 nm respectively. (2) We find that the direction of highest sensitivity (minor axis of the ellipse) is not aligned with the L/(L+M) direction, but is primarily determined by the location of the skin patch in colour space and the adapting illumination.

We therefore reject the hypothesis that post-receptoral chromatic mechanisms are shaped by evolutionary relevant skin colour changes.

Does pupil dilation trigger a shift from rod-dominated vision to cone-dominated vision?

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Background. Pupil size determines the amount of light that enters the eye, as well as how that light is focused. Consequently, pupil size shapes visual processing. However, the exact mechanisms are poorly understood. In humans, pupil size has been shown to influence detection performance, whereby large pupils improve the detection of faint stimuli. In mice, it has recently been demonstrated that changes in pupil size trigger a shift from rod-dominated to cone-dominated vision by allowing either less light into the eye, thus emphasizing rod vision (because rods are sensitive and do not require much light), or more light into the eye, thus emphasizing cone vision.

Aim. Here, we test whether fluctuations in pupil size differentially influence the detection of either red or blue targets that are presented in either parafoveal or peripheral vision. The recent results from mice lead to the (counterintuitive) prediction that detection of blue targets and peripheral targets should be impaired less by smaller pupils, because detection of these targets relies more on rod vision than on cone vision, and because rods are more sensitive than cones.

Method. Participants completed a detection task with faint red and blue stimuli shown either in parafoveal or peripheral vision while their pupil size was recorded. We focused on how spontaneous fluctuations in pupil size correlated with detection performance.

Results. The results (N = 27) suggest that detection performance is positively correlated with larger pupils in all conditions, as we have found before. Crucially, this correlation was similar for blue and red targets as well as for parafoveal and peripheral targets; that is, we do not find clear evidence for a shift from rod-dominated vision to cone-dominated vision with increased pupil size.

From colour to position: how the visual system infers location from feature distributions.

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Many models of vision assume that the visual system performs Bayesian inference, building models of the world based on prior experience and testing these models against current visual input. This principle was illustrated, among many empirical work, by Jiang et al. (2014) who found that participants could implicitly learn regularities when the position of a target had a 50% chance of appearing in a specific quadrant of the screen – and change their gaze pattern to prioritize the expected position of the target. The aim of this study is to further develop this result by investigating how participants implicitly learn probability distributions of visual features and adjust their behaviour accordingly. Eleven participants took part in a visual search experiment in which they had to detect a differently coloured diamond among 35 distractors in a 6 x 6 stimulus grid. Distractor colours were determined by a specific colour distribution. In each block, two distractor distributions were randomly interleaved. Within the predictive distribution, the target would systematically appear inside a 3 x 3 quadrant of the stimulus set, while within the unpredictive distribution, the position of the target was random. Our preliminary results show that reaction times are reduced when the target appeared in the predicted quadrant, regardless of the associated colour distribution. This suggests that a location priming effect takes place, and the behaviour of the observer is not necessarily adjusted to the probabilistic information given by the colour distribution. One explanation could be that the unpredictive distribution do not provide information that would trigger a change in the visual search pattern of the observer. We will report further experiments testing if observer's predictions are modified if both colour distribution have opposite predictive properties (e.g., both are associated with a different predicted quadrant).

An online color vision test.

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A color vision test for online testing was developed to run on a web browser, capable of estimating an observers' chromatic thresholds and measuring eye movements with a webcam. The purpose of this work was to assess whether the test can detect color vision anomalies reliably using chromatic thresholds and eye movements. Four squares with random background luminance noise were presented on a general computer screen calibrated in color and luminance. One was randomly selected to present a test color with a particular hue and saturation. Twenty-six hues were tested, on or near the dichromatic confusion lines. The observers' task was to point and select the colored square with the computer mouse. The hue saturation of each trial followed a staircase procedure. Initial hue saturation was randomly selected from a predefined saturation interval, always conspicuous for a normal color vision observer but eventually inconspicuous for a color vision deficient observer. Hue detection thresholds were estimated by averaging the last 8 responses (of 10 recorded). During the experiment, eye movements were recorded. Thirty normal observers, three anomalous trichromats, and one dichromat performed the experiment. The test could identify normal and deficient color vision by comparing color thresholds, which can be correlated with traditional color vision tests. It was also found that CVD observers generally gaze larger distances along the screen when near color confusion lines, and when unsure about the position of the colored square. These results seem to indicate that this online test can detect color deficient observers on a general computer screen, if calibrated in color and luminance. To run this color vision test only a calibrated screen is required, without the need for special hardware/software, enabling wider adoption across vision professionals.

"This work was supported by the Portuguese Foundation for Science and Technology (FCT) in the framework of the Strategic Funding UIDB/04650/2020 and the project EXPL/FIS-OUT/0398/2021"

A computational model of accommodation control exploiting chromatic aberration

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Extensive experimental evidence indicates that chromatic aberration provides a signed directional cue for the control of eye accommodation. Existing models suggest that this behavior is guided by the relative blurs detected by short, medium and long-wavelength sensitive cones. However, it is unclear how such a control strategy could be learned without supervision, for example during the early stages of visual development in human infants. In this work, we propose a computational model of the development of accommodation control that learns to exploit chromatic aberration through reinforcement learning. Our model consists of an agent that receives the foveal contrasts of color channels as inputs and the improvement in contrast as an intrinsic reward for its actions. We train it with a dataset of natural images presented at random distances. The agent is able to learn a control policy achieveing accurate focus in a small number of steps. We further evaluate the model by suddenly switching from natural images to artificial ones containing colored dots on a black background. The agent's performance decreases significantly when shown red or blue, with actions that move the focus away from the target. This accommodation divergence is also seen experimentally in the chromostereopsis effect. We conclude that chromatic aberration can be exploited to learn accurate accommodation control via reinforcement learning mechanisms. However, this agent can be deceived by artificially manipulated stimuli.

Development of a Simultaneous Selection Colour Vision Test

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Human colour vision plays a crucial role in distinguishing targets from their backgrounds, which has significant implications for everyday activities such as navigating streets and making career choices. Studies on colour vision aid in understanding its biological underpinnings and functional significance. In order to assess humans colour vision several behavioural paradigms have been developed over the years. One of the most used is the Cambridge Color Test (CCT), a computerized pseudoisochromatic test with a stimulus composed of a mosaic of circles varying in luminance whereas the participant is required to select the gap of the target (a Landolt "C" differing in chromaticity from the background) position. However, the CCT has limitations due to its time-consuming nature. To overcome this, a new computerized colour vision test called Multi Colour Vision (MCV) was developed to be more engaging and quicker, especially for children and sensitive individuals. The MCV uses the same staircase procedure, but instead of one target on the screen with only one correct answer, the MCV utilizes 6 different patches of colour, of different vectors, which the participant has to click on by using a mouse. In this study, we compare the colour discrimination thresholds of participants on both the CCT and MCV. The test protocol was analogous to the eight vectors version of CCT. An ellipse was fitted using the vectors chromatic thresholds. Paired T-tests were used to compare the results of 25 volunteers on both tests for Ellipse area (p. 0.698), major axis length (p 0.089) and axis ratio (p 0.346). Preliminary results suggest that the ellipse parameters from both tests are similar, indicating that the MCV can serve as a viable alternative to the CCT.

Amodal completion of color

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Amodal completion involves the impression of existence and properties of visually oc¬cluded parts of objects. An informal approach to its study is what I call here 'the surprise test'. It consists of first presenting a display which conveys the appearance of an occluding and an occluded figure, and then presenting a second display in which the occluding figure has been removed, and the now dis-occluded portion 'beneath' it is revealed. Various features of the newly revealed portion in the second display can be manipulated to check which outcomes appear compatible with the appearance of the first display and which are surprising, in order to obtain some insights into the properties of the mental representations of amodally completed figures. Such tests suggest that this repre¬sentation has several aspects, including that the occluded figure is con¬tinuous in the occluded portion and has no gaps, that its contours do not change direction in the occluded portion, and that its color remains the same as in the non-occluded portion. This last aspect, labeled here 'amodal completion of color' has not received much attention in the literature. In the present work it was investigated by constructing a large number of achromatic displays consisting of identical target figures embedded in system¬atically varying contexts, in order to find out which contexts are conducive for the impression of amodal comple¬tion of color and which are not. The varying contexts involved changes of geometric and photometric features of junctions along the borders of the target regions, which can cause dramatic differences in the appearance of those regions. Generally, a certain arrangement of T-junctions supported the impression of amodal com-pletion of color, and it can be argued that certain types of X-junctions supported variants of this effect as well.

Visual Perceptual Learning of Feature Conjunctions Leverages Nonlinear Mixed Selectivity

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Visual objects are often defined by multiple features. Therefore, learning novel objects entails learning conjunctions. Visual cortex is organized into separate anatomical compartments, each of which is devoted to processing a single feature. A prime example are neurons purely selective to color and orientation, respectively. However, neurons that jointly encode multiple features (mixed selectivity) also exist across the brain and play critical roles in a multitude of tasks. Here, we sought to uncover the optimal policy that our brain adapts to achieve conjunction learning using these available resources. 59 human subjects practiced orientation-color conjunction learning in four psychophysical experiments designed to nudge the visual system towards using one or the other resource. We find that conjunction learning is possible by linear mixing of pure color and orientation information, but that more and faster learning takes place when pure and mixed selectivity neurons are involved. We also find that learning with mixed selectivity confers advantages in performing an untrained "exclusive or" (XOR) task several months after learning the original conjunction task. This study sheds light on possible mechanisms underlying conjunction learning and highlights the importance of learning by mixed selectivity in such accounts.

Prolonged exposure to sub-threshold contrasts does not drive perceptual learning

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The extent to which unconscious information is processed and used by the visual system is extensively debated. Previous research suggests that simple visual stimuli that participants cannot discriminate above chance can break into consciousness with exposure, an effect that occurs early, within 100-200 trials (Schwiedrzik, C. M., Singer, W., & Melloni, L. (2009). Sensitivity and perceptual awareness increase with practice in metacontrast masking. Journal of Vision, 9(10), 1-18). We attempted to expand upon this finding in a novel experiment, where we estimated psychometric functions (PF) for contrast detection and discrimination of metacontrast-masked left or right pointing arrows, along with trial-by-trial subjective clarity on the Perceptual Awareness Scale (PAS). Based on the PFs, we chose a contrast value yielding under 60% discrimination accuracy. These steps were repeated before and after a 1000-trial training on arrows displayed at the chosen contrast (Learning condition), or a waiting time between sessions of the same duration with no training (Control condition). In both the Learning and Control conditions, subjective experience (higher mean PAS) and performance increased (lower inflection points for both detection and discrimination) between the first and second measurement session. Critically though, we found no difference between conditions (moderate Bayesian evidence for the null) in any of the three measures. For the chosen contrast, we also found no difference between conditions, for either discrimination or detection. Taken together, our converging evidence from multiple measures of consciousness suggests that if there are any effects of repeated exposure to stimuli that are initially not reliably discriminated, they do not occur early. Our findings further call into question the impact of unconscious visual information on perceptual learning, and the extent to which consciousness is "learnt", as proposed by the self-organizing metarepresentational account, a version of the higher-order-thought approach.

The Influence of a 2D versus 3D Environment on Driver Learning Outcomes during a Vehicle Overtaking Task

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Learning to drive in a simulated environment is not only safer, but also provides the driver with a realistic environment from which they can learn and be assessed. However, most driving simulations that attempt to teach or assess the users' driving ability, such as the hazard perception test, are conducted in a 2D environment. The purpose of driver training simulations is to both teach and assess driver learning outcomes, with the intention to transfer these learning outcomes to reality. Therefore, these simulations should be as immersive as possible to reflect realistic driving scenarios and improve driving-based learning outcomes. The increased level of immersion that comes with a 3D Virtual Reality (VR) simulation should therefore prove to be a more effective learning environment than one that is 2D. This study investigates whether those learning to drive will experience improved driving learning outcomes during a vehicle overtaking task when performed in a 3D VR environment compared to a 2D computer environment. Participants were instructed on how to perform a vehicle overtaking manoeuvre in either a 3D VR or 2D computer environment. After training, they were tasked with navigating through a course which required the learner to regularly overtake vehicles. Learners' ability to correctly overtake was assessed by the number of times they collided with a vehicle (oncoming and stationary), closest distance from these vehicles, and how many times they checked their mirrors during the course. Preliminary findings are discussed.

Investigating modifications to the brain's microstructure using Diffusion Kurtosis Imaging: An Examination of Visuomotor Training

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This study investigates the effectiveness of Diffusion Kurtosis Imaging (DKI) in detecting microstructural changes in the brain induced by visuomotor training. DKI is a modern MRI technique that examines the movement of water molecules in body tissue. Compared to traditional Diffusion Tensor Imaging (DTI), DKI has been proven to be more sensitive in detecting changes in white and grey matter regions.

Fourteen healthy participants completed a six-week home-based eye movement training program, consisting of 30 daily 30-minute sessions, five days a week. DKI images were taken before and after the training, and a whole-brain white matter analysis was performed using ExploreDTI software. The DKI parameters, including axial kurtosis (AK), mean kurtosis (MK), radial kurtosis (RK), and fractional anisotropy (KA), were measured.

The results showed that, in comparison to a conventional DTI analysis, DKI analysis revealed additional brain regions with significant changes in response to training, including increasing KA in six regions and decreasing AK and MK in two and four regions, respectively. No significant changes in RK were found.

These findings suggest that DKI may provide more sensitive information about microstructural changes in the brain induced by visuomotor training.

Human saccadic exploration behavior in a 5-choice reversal learning task

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Cognitive control of saccadic eye movements is often studied by reversal learning or anti-saccade experiments. We designed a new version of a reversal learning task – a 5-choice reversal learning task with alternating position-reward contingencies to investigate human exploratory behavior in saccade target selection. Exploratory behavior refers to the period after a rule change in the reward function and requires human subjects to considering previous experiences to be efficient. Subjects were required to select one out of five positions. After several consecutive trials, the rule changed. Two experiments were conducted. In the never-rewarded experiment, the rewarded position was determined from only three out of the five response options (without direct repetitions) while in the rarely-rewarded experiment, these two positions were sometimes rewarded, but four times less often than the frequently rewarded positions. Human participants were not informed about these rules, but merely instructed to maximize their reward.

We found that subjects develop an exploration bias in the never-rewarded, but not in the rarely-rewarded experiment. Interestingly, this bias evolves in a continuously progressive manner, suggesting an implicit learning process rather than explicit rule application.

This experimental study has been motivated by a prediction of a neuro-computational model of the basal ganglia, particularly with respect to a small subcircuit between the subthalamic nucleus and the external globus pallidus of the basal ganglia. Data from model simulations are in good quantitative agreement with the experimental data and suggest that the basal ganglia may contribute to such quite complex behavior by means of a simple circuit between the subthalamic nucleus and the external globus pallidus.

In conclusion, human subjects do use previous reward experiences when exploring response options after a rule change. Thus, when they search for an appropriate response, they consider first those response options that worked well in the past.

Dimensional reinforcement expectancy in a stepwise multidimensional visual discrimination task by pigeons

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Eight pigeons (Columba livia) performed a stagewise go/no-go visual discrimination task. 16 compound stimuli were created from all possible combinations of four binary dimensions: brightness (dark/bright), size (large/small), line orientation (vertical/horizontal), and shape (circle/square). The current experiment was designed in the following way: in the first stage, the pigeons learned S+ and 4 S– stimuli, sharing one (brightness), two (brightness and orientation), three (brightness, orientation, and size), or no dimension values with S+. Then, in the second stage, all 16 stimuli were presented. The dimensional learning order in the first stage was associated with stimulus learning difficulty. Stimulus discrimination was controlled by the number of dimensional disparities between non-rewarded stimuli and a rewarded one rather than by stimulus dimensional salience. At

the beginning of the second stage, there were no changes in responses to S + as well as to the 4 S– stimuli already learned in the first stage. Regarding the newly presented stimuli, the pigeons correctly rejected most of them without any learning, but some stimuli were confused with S+. More or fewer mistakes with dimensional discrimination depended on the number of S– stimuli sharing the dimension value with S+ in the first stage. Pigeon behaviour was controlled mainly by dimensional reinforcement expectancy learned in the first stage. A significant inverse correlation between the number of S– stimuli sharing dimension values with S+ in the first stage and the dimensional discrimination ratios at the beginning of the second stage was found.

Visual Aversive Learning Does Not Compromise Sensory Discrimination

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Several studies have investigated how aversive learning affects performance in the domain of vision, for example focusing on its influence on the dynamics of eye movements, binocular rivalry, and sensitivity to low-level features such as spatial frequency and orientation. A recent study found that sensitivity to orientation can be enhanced for conditioned stimuli regardless of the valence of the unconditioned stimuli, perhaps reflecting saliency processing. However, a previous study showed a decreased performance in discriminating orientations that were conditioned to highly unpleasant stimuli, with respect to neutral stimuli. In the present study, we sought to replicate such findings. Participants (N = 40) engaged in an orientation discrimination task: on each trial, they compared the angles of a pair of vertical or horizontal stripes presented in succession before and after a white noise mask, reporting the most clockwise stimulus. In the conditioning phase of the experiment, single vertical and horizontal stripes were presented sequentially to each participant, with only one of the two orientations being closely followed by rapid presentation of an image. The valence of the image was aversive for participants in the experimental group (N = 20) and neutral for participants in the control group (N = 20). The orientation discrimination task was then repeated after the conditioning phase. Results show that performance in orientation discrimination improved slightly, regardless of the valence of the associated images, suggesting that aversive learning does not modulate sensory discrimination.

Interface's visual cues in dyslexic users' procedural learning

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Dyslexia is a specific learning disability when reading is impaired. Around 5-15% of the world population suffer from it (American Psychiatric Association, 2015). In accordance with the modern view on dyslexia, people with dyslexia may suffer from an automatization deficit (Smith-Spark & Gordon, 2022). This deficit leads to implicit and procedural learning impairment (Pavlidou et. al., 2009). In our experiment, the procedural learning in adults with dyslexia was investigated in the exogenous visual cueing paradigm.

The experiment was conducted on the websites that looked like a real government webpages, where citizens can apply for various services. Participants diagnosed with dyslexia (N = 60) and control group (N = 60) had to fill in the data from documents that were specially designed for the experiment to the data entry fields on the web sites. Participants had to press the buttons after entering the data. The websites were identical to each other apart from the presence of visual cues on the buttons. The visual cues were represented as a flash in "Next" button to the right of the screen.

There were four groups of participants: people with dyslexia using the website with visual cues, people with dyslexia using the website without visual cues, and control groups using the website with and without visual cues. RT was measured.

Visual cues decreased the RT in both groups. Adults with dyslexia had worse procedural learning then the control group. In visual cues condition, participants with dyslexia revealed the same RT as people without dyslexia.

These findings revealed the automatization deficit in people with dyslexia. Also, this deficit has a possibility to be compensated with peripheral visual cues.

Perceptual learning of a Form-from-Velocity Task

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We investigated perceptual learning of a speed discrimination task in the peripheral visual field. We used a form-from-velocity task where different orientations of a virtual, motion-defined, triangle should be detected among moving dots. The target figure was distinguishable by a difference in speed of the target moving dots compared to the background moving dots. White coherently moving dots on a black background were used with randomly alternating overall motion direction (upwards,

downwards, left, right). The target form was triangularly shaped and presented in two directions (apex pointing either up or down; 2AFC). Participants had to indicate on each trial the orientation of the triangle in their peripheral visual field, while fixating a central fixation cross. During training, the figure (height: 7°, base width 6° visual angle) was presented randomly in the upper left or right quadrant at an eccentricity of 6.5° visual angle. Twenty-six normally sighted subjects (age 19-39 years) were trained on this task over four sessions, using only either their left or right eye (other eye patched). During training, a 2-down, 1-up adaptive procedure adjusted the speed of the target dots that formed the triangle resulting in speed discrimination thresholds of 70.7% correct. Before and after training the task was performed with each eye separately with a fixed speed difference between target and background to investigate the interocular transfer of learning. The results show a significant learning effect, demonstrated by significantly decreasing speed discrimination thresholds and reaction times over training sessions. Additionally, there was almost complete interocular transfer of the training as indicated by hit rates in the pre- and post-tests. The findings indicate that speed discrimination in the peripheral visual field could be improved by training, which could possibly benefit persons with central vision loss, who are reliable on their peripheral vision for daily visual tasks.

Acknowledgements: German Research Foundation (Project: DFG PL 641/1-1); ZSER e.V. (Support Association for Children and Adults with Rare Diseases e.V., Regensburg)

Perceptual learning increases perceived stimulus size at trained locations and improves untrained foveal performance

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Exploring the factors affecting outcomes of perceptual learning helps us understand the learning mechanisms and develop more efficient training paradigms. In this study, we aimed to determine whether a) training increases perceived stimulus size at trained locations? b) non-foveal training improves perceptual performance at the fovea? c) additional stimuli exposure per trial results in greater improvement in perceptual performance? We trained 20 participants on two-interval forced choice orientation discrimination tasks (3c/deg Gabor stimuli presented at two locations at 5° eccentricity). Half the participants were trained with stimuli presented at two locations randomly interleaved trial-by-trial (single-exposure training); the other half were trained with stimuli always presented at both locations (double-exposure training). Additional to the trained task conditions, an orientation discrimination task in the fovea and a fovea-periphery size discrimination task were performed before and after training. The latter typically creates a size illusion where the foveal stimulus appears larger, which has mechanistically been attributed to spatial attention. The size illusion is quantified by the perceived size ratio between identical stimuli presented at a trained location and the fovea. We found: a) perceived size ratios for trained locations/fovea were increased after training, reflecting a reduction in the size illusion despite no training on this task ($p<0.005$); b) orientation discrimination thresholds improved in the fovea for both trained ($p<0.05$) and untrained ($p<0.01$) orientations despite no foveal training; and c) double-exposure training resulted in greater threshold reduction than single-exposure training ($p<0.05$). Our results contribute to the current understanding of the association between perceptual learning and spatial attention. Perceived stimulus enlargement could indicate increased spatial attention at trained locations. Improved orientation discriminability at the fovea with non-foveal training is consistent with this learning occurring in non-retinotopic areas. Perceptual learning paradigms may take advantage of increasing stimulus exposure to increase training efficiency without increasing learning time.

Contextual learning of multiple target locations in visual search: ERP evidence

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The phenomenon of contextual cueing, where repeated exposure to a target in a consistent non-target environment speeds up visual search, is indicative of the brain's ability to use long-term memories to predict incoming sensory information and enhance attentional focus. This study aimed to investigate whether this learned environmental structure can be applied to multiple target locations within the same contextual-cueing array. Participants performed a visual search task in which search displays with two possible target locations were presented, introducing uncertainty as to where to deploy focal attention in the repeated distractor array. Our results indicated that LTM-guided attention was restricted to single (“dominant”) target positions, as indicated by faster reaction times (RTs) and more effective N1pc and N2pc evoked responses. On the other hand, processing of non-learned ("minor") target positions led to RT slowing and even and no reliable differences in lateralized ERPs relative to baseline arrays. If anything, minor target locations resulted in a reversal of an N1pc - early ERP component that may signal attention misguidance toward the dominant target location. Interestingly, the RT slowing was accompanied by enhanced N200 and N400 waveforms over fronto-central

electrodes, suggesting the involvement of control mechanisms regulating competition with learned, dominant targets. In more detail, the N200 and N400 waveforms are known to be involved in cognitive control processes, such as response inhibition and conflict monitoring. The enhanced amplitude of these waveforms suggests that the processing of non-dominant targets in the context of dominant targets requires more cognitive control resources to resolve the competition between the two. These findings provide compelling evidence for a dissociation between processing of dominant vs. minor targets in individual contextual arrays. Only the former are integrated into LTM search-guiding templates, whereas the latter require controlled processing to bias search towards them (and away from dominant targets).

Reading speed and neural dynamics related to word form recognition are modulated by the combination of multi-session tACS and reading training in Developmental Dyslexia

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Along with phonological deficits, individuals with Developmental Dyslexia (DD) show visual impairments related to the magnocellular dorsal (M-D) stream functionality, which drives graphemes and lexical units identification during reading. Growing evidence associates the M-D functionality with neural oscillations in the beta frequencies (15-25 Hz). In this study, we tested the combination of visual-attentional reading training and transcranial alternating current stimulation (tACS) applied to parietal areas, the main projection of the M-D stream. We hypothesized that this training protocol would improve not only reading speed and M-D functionality, but also visual word forms recognition performed by ventral stream areas. To this aim, two groups of adults with DD completed a reading acceleration training consisting of 12 sessions: the "tACS" group received bilateral parietal tACS in the beta band (18 Hz), while the "Sham" group received a placebo stimulation. Before and after the training, EEG data were acquired to examine event-related neural dynamics during a lexical decision task where participants were asked to perform a lexicality judgment on written words and pseudowords. In addition, working memory (WM) abilities were assessed using a digit span test, considering that they are strictly linked to reading abilities and often impaired in DD. Preliminary results showed an increased reading speed for both groups throughout the training. Furthermore, in the post-training evaluation, the tACS group exhibited a significant amplitude modulation of the P300/N400 complex of the ERPs in response to both words and pseudowords compared to the Sham group. In the tACS group, we also observed a significant improvement in WM skills. These results suggest beneficial effects of reading training combined with parietal tACS on reading skills, which are possibly mediated by a reduction in cognitive effort (i.e. improved working memory) during word form identification.

Task-irrelevant phase but not contrast variability unlocks generalization in visual perceptual learning

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Visual perceptual learning (VPL) refers to improved performance on a visual task after training. One of the hallmarks of VPL is that improved performance is specific to the training stimuli, i.e., training effects disappear after even a slight change in experimental conditions. Yet, recent research shows that variability along task-irrelevant stimulus dimensions can affect how specific VPL is. We hypothesized that variability determines which neurons undergo plasticity in VPL and depending on these neurons' invariance properties, generalization or specificity is achieved. We trained participants in orientation discrimination tasks, creating variability in different task-irrelevant dimensions of the training stimulus. In particular, we randomized spatial phase in one training group and contrast in the other. After training, we tested for transfer to a new spatial location in both groups. Phase-invariant neurons appear later in the visual processing hierarchy, compared to contrast-invariant neurons (e.g., complex and simple cells), and phase-invariant neurons have larger spatial receptive fields. We predicted that varying the phase of the training stimuli over trials would give rise to generalization in space because training would involve phase-invariant neurons with large receptive fields. Conversely, as contrast-invariant neurons appear earlier in the hierarchy, we expected to find more specificity with contrast variability. We found that randomizing phase of the stimulus led to full spatial transfer, contrary to randomizing contrast. This evidence indicates that different neural populations undergo plasticity with VPL depending on the training task demands, which results in varying generalization and specificity of behavioral improvements.

The COCO-Periph Dataset: Benchmarking and Training Deep Neural Networks Using Human Peripheral Vision

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There is increasing interest in using Deep Neural Networks (DNNs) to model human vision, but standard DNNs often fail to account for aspects of human vision — such as foveation and peripheral vision. It is difficult to obtain labeled data on human visual behavior on a large enough scale to use in DNNs, but we do have general models of peripheral vision like the Texture Tiling Model (TTM), which has been highly tested as a good predictor of human performance in the periphery. Running TTM can be thought of as an image pre-processing step similar to blurring an input to simulate acuity loss, and if pre-computed, it could be used with any vision DNN trained for a variety of tasks. To get the benefits of DNNs, which can model complex visual tasks, and the benefits of TTM, which can predict performance in the periphery, we provide a dataset called COCO-Periph. COCO-Periph consists of the MS-COCO dataset rendered with a uniform pooling version of TTM. We use this uniform TTM to simulate the amount of information available at 5, 10, 15, and 20 degrees everywhere in an image. The rendered images can also be stitched together to flexibly simulate a fixation anywhere in an image. COCO-Periph is a dataset of images in the COCO format, so it can be flexibly used with many state-of-the-art DNN vision models without architecture modifications or additional training; it also benefits from the rich annotation set of COCO which includes tasks like object detection and semantic segmentation. Using COCO-Periph, we show that a convolution-based DNN object detection model performs poorly when viewing uniform-TTM images, but it can improve when training on COCO-Periph. Overall, COCO-Periph provides a benchmark for testing how well DNN models perform when operating on information available in the human visual periphery, and it can be used in the future to train DNNs that are better at predicting human performance in the periphery.

Distractor suppression operates in retinotopic coordinates

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The present study used the additional singleton task and showed that observers are biased away from the location that is likely to contain a distractor. Consistent with previous studies, it suggests that through statistical learning the weights within the spatial priority map are adjusted: the likely distractor location becomes suppressed. The question we addressed here was whether this suppression operates in retinotopic (relative to the eyes) or spatiotopic (relative to the world) coordinates. In the current design, there were two displays next to one other and observers performed the additional singleton task in one display and after several trials made an eye movement to the other display. Because of the eye movement, the previous retinotopic location became the spatiotopic location in the other display and the retinotopic location moved in space. The results showed that attentional suppression operates in retinotopic coordinates. These results might be surprising since it provides constraints on distractor location suppression learning and questions its relevance in natural settings. However, it is important to note that in many real-world settings, such as driving a car, viewpoints are relatively stable, which makes distractor suppression in retinotopic coordinates sufficient, such as suppressing blinking advertisements alongside the road.

Generating candidate cognitive models for the Posner cueing task

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GEMS is a cognitive architecture that uses genetic programming (a form of artificial intelligence that evolves programs over generations) to produce models of cognition. In particular, the system combines a number of operators – simple cognitive processes, such as 'move visual attention' – into a model, and compares the model's output to human behavioural data. Models with the best fit then proceed into the next generation. Through applying the GEMS methodology to published behavioural data for the Posner cueing paradigm (derived from Arjona, Escudero & Gómez, 2016), we extend our understanding of the underlying cognitive mechanisms and determine the potential strategies being used. The Posner cueing paradigm has been used extensively to measure visual attention, due to its simple and easy-to-implement design and the robust results it produces. The task begins with a directional cue, followed by a target stimulus that is in either the cued location (valid cue) or another location (invalid cue). Participants respond with the location of the target as quickly and accurately as possible. Typically, faster and more accurate responses are given when the cue is valid. The Posner cueing paradigm is generally regarded as a visual attention task; however, it involves additional mechanisms, such as those related to decision-making. Learning mechanisms are also likely engaged; responses are quicker when most of the trials in a block are valid, demonstrating a

sensitivity to overall probability. Further, cueing occurs across perceptual modalities (e.g., a visual cue affects an auditory target), suggesting the influence of cross-modal processes. Regardless, different elements of cognition are often studied in isolation. A key benefit of GEMS is that it allows investigation into the interplay between different cognitive mechanisms. We discuss the strategies produced by GEMS, suggest directions for future experiments and consider implications for our understanding of the Posner cueing task.

Reading acceleration training combined with bilateral parietal tACS at beta frequency reduces regressive fixations and saccades in Developmental Dyslexia

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Individuals with Developmental Dyslexia (DD) suffer from impairments in letter segregation as well as in planning/executing optimal saccades during reading, leading to reduced reading speed/accuracy. Such deficits are linked to impairments of the magnocellular dorsal (M-D) stream, which has a key role in contour integration/segregation and consequently in guiding letter identification. Increasing evidence linked different functional aspects of the M-D stream to the oscillatory activity of the parietal cortex in the beta band (15-30 Hz). Here we aimed at increasing reading speed by combining a reading acceleration training with high-definition transcranial alternating current stimulation (tACS) in adults with DD. Participants took part in a 12-sessions training protocol. In each session, two groups of adults with DD were administered a reading acceleration task for 40 minutes. In the fast-paced condition, sentences were presented on a computer screen but faded progressively. After each sentence, a comprehension question was used to determine the fading speed, which was continuously adjusted based on performance. Before and after the fast-paced condition, reading speed was recorded in a self-paced reading condition. During the task, the tACS group received beta (18 Hz) tACS over bilateral parietal sites while the Sham group received a placebo stimulation. Gaze data were recorded for both groups. Preliminary results indicate that the reading speed recorded before the fast-paced condition was progressively increased for both groups throughout the training sessions. Importantly, the reading speed recorded after the fast-paced condition was increased more in the tACS group. Moreover, the tACS group also showed a greater reduction of regressive fixations and saccades over the course of the training with respect to the Sham group. Overall, the present results suggest that modulating beta-band activity across parietal sites can be used to ameliorate the efficacy of visuo-attentional reading trainings and to optimize oculomotor control in DD.

Challenging the spatial modality of a digital Corsi task by manipulating spatial updating and mental rotation

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The Corsi (block tapping) task is a standard and widely used experimental as well as diagnostic paradigm to assess visuospatial working memory. Thus, it tests for the memory and reproduction of spatiotemporal sequences of varying length, a cognitive competence that is also important in other spatial tasks such as route planning and navigation. In Corsi tasks, participants have to variably recruit and allocate visuospatial memory, pay attention, and plan motor behaviour to be able to reproduce the spatiotemporal sequences appropriately. In order to investigate the spatial component involved during the performance of a digital Corsi task, we systematically manipulated this process and challenged it by introducing additional spatial tasks during the retention of the Corsi material.

In this study, three manipulations were tested in a within-subject design, demanding subjects' spatial memory through i) Corsi sequences increasing in length, ii) spatial updating (SU), and iii) mental rotation (MR). SP was required when subjects had to walk to a new position around the Corsi setup. Otherwise, MR was required when the Corsi sequence was rotated during the retention phase. In consequence, combinations of two additional spatial tasks (SU and MR) result in the Corsi conditions 'static' (no SU | no MR), 'rotate' (no SU | MR), 'walk' (SU | no MR), and 'rotate+walk' (SU | MR). With this study, we present data showing that besides the well-known spatial requirements of a Corsi task, additional working memory resources are demanded in the walking and/or rotating conditions supporting processes such as spatial updating and mental rotation.

The effect of phasic and tonic alerting on visual perception

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Recent studies have found effects of phasic alerting on visual perception. However, the link between tonic alerting and visual perception is often overlooked in cognitive psychology. In this talk, I will present a series of preregistered studies investigating

the effect of both phasic and tonic auditory alerting on distinct perceptual processes, unconfounded by motor components. We combined a phasic alerting/tonic alerting/no-alerting design with a pure accuracy-based letter recognition task. Computational modeling was used to examine the effects of phasic and tonic alertness on threshold of conscious perception, visual processing speed, visual short term memory capacity, and selectivity. Results show that phasic alerting affects visual perception by increasing the visual processing speed, replicating previous findings. However, we did not find an effect of phasic alerting on threshold of conscious perception, visual short term memory capacity, nor selectivity. Furthermore, the results did not reveal any effects of tonic alerting on visual perception. These findings provide new insight into the mechanisms underlying the interaction between alerting and visual perception. I will discuss the implications of these results in relation to a newly developed mathematical model of the relationship between levels of alertness and visual perception. Acknowledgements: Research was supported by a Grant from the Independent Research Fund Denmark (9037-00169B).

Do we use depth when selecting objects from visual working memory?

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Internal selective attention enables us to access visual contents from working memory to prioritise them for upcoming behaviour. Recent studies using 2D displays have revealed how internal selective attention is moderated through memorised locations (even when location is never asked about) and engages the brain's oculomotor system. It remains unclear whether the reliance on location and the use of the oculomotor system extends to the depth dimension when selecting memorised visual objects in immersive 3D settings. To address this, we set up a virtual-reality task in which participants had to memorise the shape and colour of two objects that were briefly displayed at different distances (near and far), without ever asking about object location. After a delay, one of the memoranda was cued through colour, prompting participants to access and prioritise the associated shape for later report. We focused our analysis on patterns of gaze convergence/divergence following the colour cue, comparing trials in which cued objects happened to be presented at near vs. far positions at encoding. Analysis from a preliminary dataset revealed patterns of gaze vergence that suggest the use of memorised depth, consistent with the engagement of the oculomotor system during mnemonic selection from within a three-dimensional spatial layout of visual working memory.

Effect of group homogeneity on ensemble bias visual working memory of individual representation.

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Ensemble representation, a process that summarizes the information of the complex scene, has an influence on the working memory of individual items. Several studies have shown that we might use the mean value as an ensemble representation of the group. However, it remains unclear what the summary statistics we use to represent the whole group of objects. Therefore, we aimed to evaluate whether the homogeneity of the group also affected the memory of individual representations. In this study, participants performed a delayed match to the sample task, in which a group of different-sized circles was shown at random locations after the target circle was randomly probed. Participants had to estimate the target size by method of adjustment. In the first experiment, we modified the homogeneity of the circles that are either larger or smaller in size than the mean while keeping the mean sizes of circles constant. The results showed that the remembered target size was biased towards the size of the homogeneity circle in the set ($F = 8.640$, $p < 0.001$). In the second experiment, to replicate this finding and to explore the influence of mean in the group that have similar objects, we modified the mean size against the size of the homogeneity circles which was made constant. Interestingly, the results showed that there was no difference in target response although the mean size was changed ($t = -1.456$, $p = 0.149$). Our findings suggest that in particular situation when the group had more similar objects, the ensemble representation uses the mode value or homogeneity as a statistical summary of the groups.

Beyond the magical number of seven: Subitizing does not reflect a pre-categorial process limited to 7 items but benefits from cardinal patterns way beyond this so-called magical frontier of iconic memory

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Subitizing refers to the rapid perception and reasonably good estimation of small numbers of items. Usually, subitizing is linked to the iconic memory and, thus, theorized as pre-categorical processing. However, everyday observations show that cardinal patterns of items, e.g., the Gestalt of the layout of dice numbers, are much easier and more accurate to detect and process than non-cardinal, random patterns, even if more than one dice number has to be processed. 25 participants had to estimate as fast as possible 1-18 dots which were presented very shortly for only 32 or 500 ms (compared to a null condition with unlimited presentation time). The dots were arranged as cardinal or non-cardinal patterns. Cardinal patterns were realized by 1-3 different layouts of dice numbers; non-cardinal patterns that took up the same general areas and so the same visual angles but were jittered variants of the cardinal ones. We performed Bayesian factorial analysis using bi/tri-linear and sigmoid linear mixed models to quantify the effects of experimental manipulations on response times (RTs). The RTs of the non-cardinal patterns increased linearly with the number of dots, while we revealed approximately constant RTs for cardinal patterns, even when the numbers had to be captured across different dice layouts. This indicates that subitizing is not based on pre-categorial iconic memory processing but benefits from cardinal and highly familiar patterns such as learned dice layouts—even if the number of dots substantially outnumbers typical "magical numbers" of seven plus minus two.

Are microsaccades biased similarly during external and internal shifts of covert attention?

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Selective attention can be directed to external visual sensations as well as to internal visual representations held in working memory. It has long been known that the covert shifting of attention to (anticipated) external sensations is associated with directional biases in microsaccades. We have recently demonstrated that directional biases in microsaccades also occur when covertly shifting attention to internal visual representations maintained within the spatial lay-out of working memory – when there is no incentive for overt shifts of gaze. In the current project, we aimed to directly compare spatial biases in microsaccades when attention was directed to either external visual stimuli or internal representations of those same stimuli in working memory. Non-spatial colour cues directed attention to one of two visual objects, presented to the left and right of fixation. Cues either appeared before or during stimulus presentation (externally directed attention) or after stimulus presentation, while retaining the visual objects in working memory (internally directed attention). Our data confirmed profound spatial microsaccade biases during both externally and internally directed covert shifts of attention. Interestingly, these biases were even more robust (in addition to being slightly delayed) when directing attention internally, when there was no incentive for overt shifts of gaze. While covert-attention demands resulted in a mixture of micro- and macro-saccades when directing attention in perception, gaze biases in working memory occurred exclusively in the microsaccade range. Together, these data (1) reinforce the utility of microsaccades biases as a powerful tool for tracking covert attention in both external and internal domains and (2) bring the paradoxical insight that eye-movement biases by covert attention may be even more reliable in cases where there is in fact nothing to look at.

Resting-state electroencephalographic change in response to combined tDCS and working memory training in healthy older adults

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Working Memory Training combined with transcranial direct current stimulation (tDCS) shows promise in counteracting physiological cognitive decline, by leveraging the brain's neuroplasticity. It remains unclear, though, if these combined protocols can induce changes in brain activity at rest, as measured by electroencephalography (rs-EEG). Importantly, rs-EEG can predict training gains and long-term outcomes in combined tDCS and working memory training protocols and can index brain reactivity, i.e., how quickly the brain can switch between vigilance states (eyes open and eyes closed), which in turn predicts memory performance.

Forty healthy older adults were double-blindly assigned to a sham and active stimulation group. Task-related EEG and rs-EEG were collected before (pretest) and after (posttest) five consecutive days of 20 minutes of 2mA anodal tDCS of the right dorsolateral prefrontal cortex and working memory training, and at follow-up after approximately one month. From rs-EEG, we calculated power in the individual theta (average over frontal-medial electrodes) and alpha (averaged over occipital electrodes) range. We hypothesized training-induced posterior alpha and medial-frontal theta band power changes to be modulated by tDCS.

Posterior alpha power, but not theta, was significantly modulated by the interaction of training sessions (pretest, posttest,

and follow-up), brain state (eyes open or closed), and initial working memory capacity. Follow-up analyses revealed that it was only individuals with low working memory capacity who showed a significant increase in alpha power in the eyes closed condition, but no effects of stimulation were found. These findings provide insights into the breadth of the impact of combined tDCS and cognitive training on rs-EEG.

ACCURACY OF SPATIAL REPRESENTATIONS OF STATIC AND DYNAMIC SCENES IN WORKING MEMORY

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Spatial memory appears to be supported by multiple internal representations – mental images reflecting the topological and metric characteristics of the environment. There are two types of representations: egocentric spatial representations (ESR) and allocentric spatial representations (ASR) encoding self-to-object and object-to-object spatial information respectively. A lot of studies investigated ESR/ASR mechanisms using static scenes as stimuli but little data is known about ESR/ASR of dynamic scenes. We studied the accuracy of ESR/ASR formation of static and dynamic scenes in working memory. Working memory processing initiated using a dual task methodology. Eight static and eight dynamic scenes consisting of 4 objects located in different 3D positions were constructed and presented using VR HMD technology. Thirty seven participants were tested. Their task was to remember virtual objects and their locations and then to reproduce a memorized scene in a virtual space using ESR or ASR viewer's positions. The accuracy of identification and localization in metric and topology units was evaluated. The results showed that the accuracy of object's identification for dynamic and static scenes was statistically insignificant both for ESR (p=0.17) and ASR (p=0.09). The metric accuracy of static scenes was higher for ESR (p=0.001) and ASR (p=0.03). But topological accuracy of dynamic and static scenes were not differ significantly both for ESR (p=0.06) and ASR (p=0.57). The results showed the important role of coding topological spatial information during memorizing dynamic scenes in working memory. This is probably closely related to the «biological motion» recognition, which allows the rapid selection of moving objects from the environment and the reconstruction of the perceived objects shape.

The study was funded by Russian Scientific Fund project №19-18-00474-P.

Does attention to internal visual content in working memory selectively affect distractor intrusions at memory-congruent locations?

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Selective attention can be directed not only to external visual inputs, but also to internal visual contents held in working memory. For example, a retrospective informative cue presented during visual working-memory maintenance enhances subsequent performance for the cued item. Previous studies have shown how such internally directed selective attention is mediated through memorized locations as shown, for example, through spatial biases in gaze. We studied how such internal selective attention affects distractor processing and memory-distractor confusability. Human observers completed a continuous orientation-recall task where a distractor orientation was presented after the retrospective cue with varied cue-distractor intervals at memory-matching or non-matching locations. Preliminary results reveal distractor intrusions whereby orientation reports of cued memory content are biased toward distractors, but only when these distractors are presented at locations that match the memorized location of the cued memory content, and only if distractors appear within a certain time from the retrospective cue that directs internal attention. These findings provide novel insights into how internally directed attention interacts with the processing and integration of external visual percepts.

Investigating the temporal dynamics of top-down attention during single- versus dual-color search

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Lately, a number of psychophysical studies on human visual perception and attention demonstrated rhythmic fluctuations in the time course of behavioral performance from around 4 to 14 Hz, matching the timescale of ongoing oscillatory brain activity. Further, studies reported that the speed of these fluctuations decreases by half during the monitoring of two versus one attended locations or objects. Critically, attention is often top-down directed through templates of task-relevant features held in visual working memory (VWM). Sensory input is then compared to the templates until a match is achieved. Prior research

from our lab showed that while holding two target features in VWM, discrimination performance exhibits a temporal profile of ~ 4 Hz per feature. Presently, however, it is unknown whether the simultaneous monitoring of two versus one feature templates during visual search leads to a similar rhythmic performance fluctuation.

To elucidate this issue, we ran two dense-sampling experiments (i.e., we varied the template-to-target intervals densely across a broad range of such intervals) with a visual search task under single- and dual-color search conditions. With target colors changing on every trial, participants encoded either one or two colors and subsequently searched for the color-defined target among three distractors. By testing search performance based on VWM contents at 100 different time points after encoding, we estimated the time course of template-based performance separately for the single- and dual-color search conditions.

Our findings provide novel insight into the temporal dynamics of VWM representations and contribute to the ongoing debate on whether search for more than one target feature occurs in parallel or switches rhythmically between features. Particularly, together with previous work from our lab suggesting a cyclic re-activation of task-relevant features in VWM, results from the present study shed light on current beliefs regarding a simultaneous operation of multiple templates guiding search.

Attentional template precision during preparation for visual search

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Visual search is guided by working memory representations (templates) of target defining features which are activated prior to search. We tested the precision of such memory-based target representations by presenting observers with difficult versus easy search tasks in which we expected high- versus low-resolution target templates to be required for target detection, respectively. In difficult search displays, colour-defined targets were accompanied with two target-similar colour distractors (different hues but same colour category). In easy search displays, targets were shown together with two target-dissimilar distractors (different colour categories). To make search displays physically identical between task conditions, target-dissimilar and target-similar distractors were also shown during difficult and easy search, respectively, but at search-irrelevant display locations. Search displays were presented every 1600ms and task-irrelevant probe displays were flashed between them every 200ms (rapid serial probe presentation). Probe displays contained a colour singleton in either the target colour, or a target-similar or target-dissimilar distractor colour. N2pc components of the event-related potential, indicative of attentional capture, were measured in response to the colour singletons. In both tasks, target-colour probes triggered N2pcs which increased in amplitude across the search preparation period until they were largest for probes immediately preceding the next search display. Target-dissimilar distractor colour probes, however, never triggered N2pcs. This N2pc pattern mirrors previous findings and reflects transient activation of colour-selective templates in preparation for search. Importantly, target-similar distractor colour probes did trigger N2pcs, but only in the easy search. This suggests that participants adopted a precise hue-specific template when target and distractor colours were similar, and search was difficult. But when search was easy because target and distractor colours were dissimilar, target colour representations were categorical and target-similar colours captured attention during search preparation. Taken together, attentional template precision seems to be adjustable to meet different levels of task difficulty.

Visual Search and real-world object representations in aging

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In aging there is a lack of understanding of the influence of the similarity between real-world objects in Older Adults' (OAs) visual search behaviors. Traditional research examining the influence of similarity on OA's visual search performances has manipulated the perceptual features of geometrical stimuli. We identified two main features characterizing real-world objects: 1) conceptual features (semantic categorization) and 2) perceptual features (color). The investigation of the influence of these two features is an interesting question given that aging is exemplified by seemingly intact semantic (conceptual) memory, whereas visual perceptual abilities are found to decline in aging. To test the influence of these two features of similarity, we designed a visual search task and presented OAs and Young Adults (YAs) with real-world objects varied in conceptual and perceptual similarity. We initially found no age-related effect of similarity when using a small set size (5, 7 and 10 objects). However, in a follow up study with a larger number of objects presented (10, 12 and 15), we resultantly found an age-related influence of perceptual similarity on OA's performances. Specifically, the findings indicated target-distracter perceptual similarity led OAs to slower performances. Our findings overall suggest 1) a higher amount of real-world objects leads to age-related effects of similarity in a visual search task, 2) target-distracter perceptual similarity leads to slower OA's performances in searching for a target.

Prolonged Oculomotor Inhibition for increased Working Memory Load during Maintenance and Retrieval

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Involuntary eye movements occur constantly even during fixation and have been shown to convey information about cognitive processes. They are inhibited momentarily in response to external stimuli (oculomotor inhibition, OMI), with a time-course and magnitude that depend on stimulus saliency, attention, and expectations. It has been recently shown that working memory load for numbers modulates microsaccade rate, but the generality of the effect and its temporal properties are yet unclear. Our goal was to investigate the relation between OMI properties and working memory load for simple visual shapes, in the encoding, maintenance and retrieval stages. Participants (N=26) maintained central fixation and self-initiated trials in which they had to memorize and then match briefly flashed stimuli while their eyes were tracked. The stimuli consisted of three simple colored shapes, with small arrows indicating the shapes to be memorized: 1, 2, or 3 items, corresponding to low, medium, and high load. After a 1s retention period, one colored shape was briefly flashed, and the participants had to report if it matched any of the memorized shapes. The microsaccade event-related rate modulation and temporal properties were analyzed for the separate events of memory encoding and retrieval, as well as the intermediate maintenance period. For both the maintenance and retrieval periods, the microsaccade inhibition was stronger and longer when more colored shapes had to be remembered. This occurred even though the physical stimuli were identical in number in all conditions. An opposite tendency was observed during encoding. The pupil dilation was also affected by load, but not the eye-blinks. Maintaining and retrieving more items from working memory is associated with longer and stronger oculomotor inhibition. This suggests that event-related OMI is generally related to the associated processing time and load, similar to the prolonged OMI found in response to oddballs.

Distracted on Campus? The Influence of Distractions on Outdoor Visual Search and Memory

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Despite of the longstanding tradition of the study of visual search, the exploration of this behavior in environments closer to everyday life remains relatively scarce. In the present study, we examined whether and how different types of distractions affect search performance and memory for objects during visual search in a real-world setting. To this end, participants were instructed to search for 80 different targets (half of them present) across eight locations on a university campus. The participants were assigned to one of four conditions: no distraction, auditory distraction, executive working memory load, or time pressure. Results showed that regardless of the distraction condition, search time was longer, and fewer errors were made in target-absent than in target-present trials. However, executive working memory load had a significant impact on search accuracy, leading to higher error rates than the auditory distraction condition. The executive working memory load also resulted in poorer memory performance for targets compared to the no distraction condition. Memory for the searched objects, as well as their locations were better for targets that were present during the search task than for absent targets. Together, these findings reveal similarities to traditional visual search experiments in laboratory settings, and emphasize the importance of executive working memory for visual search processes.

Flipping the Switch in Attentional Control: Proactive Suppression and Capture Flexibly Guide Visual Attention Based on Search Goals

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While visually searching for different targets across time, visual attention is assumed to be guided by flexible working memory representations storing the features necessary to identify the target among irrelevant distractors. The present study tested whether working memory representations facilitate attentional guidance to target features or can be used flexibly to trigger facilitation or suppression depending on current task demands. We instructed participants to either search for a target by a task-relevant positive (e.g., blue or red) or a negative feature (e.g., not red) and search tasks (positive vs. negative) alternated or repeated randomly from trial to trial. Before each target, we presented a spatial singleton cue with positive, negative, or irrelevant features. We measured search times depending on whether the singleton cue was presented at the same (valid condition) versus a different position (invalid condition) than the target. When participants searched for the target by a negative feature, search was slower in valid than invalid conditions with negative color and nonmatching cues, indicating that both singleton-cue features were similarly and proactively suppressed. In contrast, when participants used a positive color as a search criterion, search was faster in valid than invalid conditions with positive color cues, indicating attentional guidance

toward the cue. Our results suggest that working memory representations for positive and negative features flexibly guide attention through guidance or suppression based on currently pertaining instructions but operate at different levels of feature selectivity.

Maturation of face- and body-selective regions in fusiform cortex across childhood and adolescence

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Previous research has highlighted cortical thinning as a key process of cortical maturation across the brain during development. However, recent work challenges this notion, suggesting that, in visual ventrotemporal cortex (VTC), an apparent thinning of cortex in adults compared to children may emerge from greater myelination leading to different image intensities and a 'shift' in the grey-white boundary in MR images. In addition to microstructural changes, there is evidence for development of functional selectivity of VTC, with reduced selectivity in fusiform face area in children relative to adults. Here, using ultra-high field 7T MRI, which affords higher resolution compared to previous studies, we specifically assessed what functional and structural changes underlie the maturation of face- and body-selective regions in VTC across childhood and adolescence by combining multimodal imaging data. We collected functional and quantitative MRI data in typically-developing children and adolescents aged 8-18, and assessed quantitative changes in functional selectivity and microstructure in VTC's face- and body-selective regions. We found evidence of increasing face-selective activation of fusiform cortex across late childhood and adolescence, but no increase in body-selectivity across these ages, consistent with previous research. Our proxy measure of myelination, R1, indicated increased myelination with age in both face- and body-selective fusiform cortex. Importantly, with the resolution afforded by ultra-high field MRI, we found no evidence of cortical thinning in functional face and body regions of VTC. Together, our findings provide support for increasing cortical myelination as a key process of change during late development of fusiform cortex, as well as increased functional specificity of face- but not body-selective areas. Critically, we find no evidence for cortical thinning across late childhood and adolescence. Overall, our results provide novel insight into the structural and functional changes underpinning development of face- and body-selective cortex through adolescence.

The eyes detect fearful faces before gaining visual awareness

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Threat-related stimuli like fearful faces are preferentially processed by the brain, even in the absence of visual awareness. Previously, we demonstrated that the eyes move towards fearful faces and away from angry faces in the absence of visual awareness (Vetter, Badde, Phelps & Carrasco, 2020, eLife). In the current study, we investigated the processing stages during which fearful faces gain visual awareness. We addressed two questions: 1) which eye movement patterns accompany the breaking-through of fearful faces into visual awareness and 2) whether fearful voices could have an effect on break-through or eye movements. We suppressed intact and scrambled fearful faces from visual awareness using continuous flash suppression and paired them with fearful, neutral or spectrally inverted voices. As indicators of visual processing levels, we tracked eye movements and gathered objective and subjective behavioural measures of visual awareness. We found that fearful faces broke through to visual awareness more often than scrambled faces, in line with earlier findings (e.g. Yang et al., 2007), and confirming the preferential processing of fearful faces. In those trials where participants subjectively reported having seen at least a brief glimpse of the visual stimulus, we found that the eyes move towards the stimulus even when participants are yet unable to localise the stimulus correctly. Critically, the eyes moved towards fearful faces earlier than towards scrambled faces. Voices showed no interaction effects with visual stimuli in neither eye movement nor behavioural data. Our findings demonstrate that during the process of visual stimuli gaining awareness, the eyes detect visual stimuli first even when they cannot be localised yet, and this effect is particularly pronounced for fearful faces. The absence of an effect of voices suggests that multisensory integration may not easily occur in the absence of visual awareness. Overall, we conclude that the eyes are early detectors of fearful faces, both in the absence of awareness, and during the process of gaining visual awareness.

Intracerebral electrical stimulation of the right FFA transiently impairs face identity recognition

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Human face recognition is supported by a network of face-selective regions in the occipito-temporal cortex as evidenced by neuroimaging and intracranial electrophysiological studies. Among all regions of the network, the largest and most consistent face-selective neural activity has been observed in the middle portion of the right lateral fusiform gyrus ('fusiform face area(s), FFA), a hominoid-specific region correlated with conscious perception of faces in humans. However, brain lesions causing prosopagnosia typically encompass wider regions, sometimes outside of the right FFA, and focal electrical stimulation of this region has only led to perceptual face distortion without recognition impairment. Hence, direct evidence for the critical role of this region in face identity recognition (FIR) is still lacking. Here we report the first case of behavioral FIR impairment during focal electrical stimulation of the right FFA. Upon stimulation of an electrode contact within this fMRI-defined region, subject CJ, who shows typical FIR ability outside of stimulation, was transiently unable to recognize the identity of faces shown in front of her. Importantly, her impairment was extensively documented and video-monitored with nonverbal tasks, requiring to point to a famous face among strangers and to match pictures of famous or unfamiliar faces presented simultaneously for their identity. Her performance at comparable tasks with other materials (names, buildings) remained unaffected by stimulation at the same location. During right FFA stimulation, CJ consistently reported that simultaneously presented faces were the same identity, with little or no distortion of the face configuration. Independent electrophysiological recordings showed the largest neural face-selective and face identity activity at the critical electrode contacts. Altogether, this extensive multimodal case report provides the first direct evidence of a causal role of the right FFA in in the ability to pick out the idiosyncratic visual cues that makes every face unique, independently of long-term face familiarity.

Backward masking coarse-to-fine processing of faces in the human visual system.

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According to coarse-to-fine theories, initial stages of visual processing involve the rapid transmission of low spatial frequency (LSF) signals from V1 to ventral, dorsal and frontal regions to form a coarse representation of the input, which is later sent back to V1 guiding the processing of fine-grained high spatial frequencies (HSF).

Using neuroimaging we investigated the role of V1 in coarse-to-fine processing. We selectively disrupted processing of coarse or fine content of full-spectrum face stimuli using SF-filtered backward masks (LSFs: <1.75cpd, HSFs: >1.75cpd) at different stimulus onset asynchronies (SOAs; 50,83,100,150ms). Consistent with coarse-to-fine proposals, we found that masking of LSFs disrupted V1 activity initially, progressively decreasing in influence, while masking HSFs showed an opposite trend. This pattern was also observed in ventral, dorsal and frontal regions. Additionally, the fusiform face area (FFA) showed increasing responses as SOA (i.e. face visibility) increased. These findings suggest involvement of V1 in recurrent interactions with higher-level regions integrating top-down inferences with incoming visual signals.

To investigate behavioural consequences of disrupting coarse-to-fine processing, we conducted a similar backward masking design psychophysically. In a delayed identity matching task with celebrity faces, the signal-to-noise ratio (SNR) of the target face was varied using a staircase method to determine the SNR threshold for 75% accuracy. As expected, the SNR threshold decreased with increasing SOA for both LSF and HSF masking, with a steeper decrease for HSF masking, mirroring FFA results. These results suggest that HSF processing elicits slower and more sustained responses compared to LSF processing, in line with coarse-to-fine theories.

We currently investigate the notion that recurrent processes increase with decreasing stimulus visibility, as predicted by recurrent processing models. Our research shows that V1, dorsal, ventral, and frontal regions are involved in coarse-to-fine recurrent processing, with behavioural implications for complex tasks such as human face identity recognition.

Effective connectivity of the right fusiform face area through concurrent intracerebral electrical stimulation and frequency-tagged visual presentation

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The neural basis of human face recognition has been extensively studied for decades, but the functional organization of the cortical face network remains largely unknown. To define the effective connectivity of this network, we apply direct electrical stimulation through intracerebral electrodes (SEEG) and

combine it with fast periodic visual stimulation. Electrodes implanted intracerebrally in drug-resistant epilepsy patients allow us to stimulate a local node of the network and record the functional activity of other implanted regions, with high spatial and temporal resolution.

We describe this original combination of techniques in one case: CJ, a right-handed 43-year-old woman with refractory focal epilepsy, excellent face recognition ability, and key implantations in face-selective regions of the right lateral fusiform gyrus (latFG; fusiform face area, 'FFA') and bilateral ventral anterior temporal cortex. This patient is of note as it constitutes the first case of transient face identity recognition impairment induced by focal stimulation of the right FFA. CJ observed 60-second sequences of natural images of familiar faces presented at a 6Hz rate, while focal stimulation (1.2mA, 55Hz) was applied to the face-selective right latFG for 10s.

During stimulation, we found a reduction of significant 6Hz responses to familiar faces not only locally (right latFG), but also in remote face-responsive areas of the right and left anterior temporal lobe. As these electrophysiological effects represent an explicit modulation of responses to familiar faces, they suggest functional connectivity between the affected areas. Interestingly, the stimulations that led to significant electrophysiological effects were also associated with the clearest behavioural impairment: during these stimulations, the patient was unable to recognize the familiar faces displayed on the screen.

This original combination of techniques appears to be effective and its application on a wide sample of individual brains could provide key information regarding the connectivity of well-defined functional brain networks.

A robust neural index of automatic generalization across variable natural views of familiar face identities

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Humans' excellent ability to recognize the same identity across different views of a same familiar face identity is well documented. However, this ability is generally measured with explicit behavioral tasks involving many processes. Here we aimed at providing a simple implicit neural index of this ability using electroencephalographic (EEG) recordings coupled with fast periodic visual stimulation. Various images of two famous face identities were presented for 15 sec, alternating at a frequency rate of 6 Hz. This stimulation was preceded by a 15 sec adaptation period to either (1) one of the two alternating face identities (adaptation condition) or (2) another identity not present in the alternating sequence (control condition). For each identity, various unsegmented natural images (from a pool of 30 images), with the face varying in size, expression, lighting, head orientation, etc. were presented. EEG signals (128 channels) of 16 healthy participants were analysed in the frequency domain to compare the amplitude of the 3 Hz EEG response, reflecting asymmetry between the two alternating faces. Results show a significantly larger amplitude of EEG activity at 3 Hz, i.e., the identity repetition rate, for the condition with adaptation to one of the two alternating face identities (0.39±0.08 μV) than for the control condition with irrelevant adaptation (0.16±0.07 μV). This 3 Hz evoked response for familiar faces was maximally localized over the right occipito-temporal region, a region particularly important for face recognition. As expected, no significant amplitude difference was found between the two conditions for the 6 Hz stimuli presentation frequency, reflecting general processes. To conclude, we provide an ecological, objective, and sensitive stimulation technique to implicitly measure an individual's ability to generalize identity across different natural views of familiar faces, with the potential for providing a biomarker of impairments at this function in neurological conditions (e.g., Prosopagnosia, Alzheimer's disease).

Horizontal cues enable viewpoint tolerant recognition of human face identity

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The recognition of individual identity despite variations in face appearance is a core and challenging function of the human visual system. Past evidence shows that humans are particularly sensitive to horizontal cues when identifying faces. It is generally assumed that face identification is tuned to horizontal cues because most of the energy (i.e., contrast) in the face image is contained in this orientation range, due to the horizontal structure of the main features (eyes, mouth…). The horizontal range is also where the front views of faces of different identities differ the most. We show in a parallel project that the horizontal contrast conveys not only these feature cues but also information about surface shading. Here, we examined whether the preference for horizontal cues is resistant to changes in viewpoint.

Human observers performed an identity recognition task with face stimuli presented under seven different viewpoints by rotating yaw (from full-front view to profile views) and filtered to preserve contrast in selective orientation ranges (from 0° to 157.5° in steps of 22.5°). We found that the Gaussian function describing human identification performance as a function of orientation always peaked around the horizontal angle, irrespective of viewpoint. Using MATLAB-coded model observers, we show that contrast in the horizontal range conveys the richest cues to identity in full-front views, but less so in 3/4 and

profile views. Importantly, we found evidence that the horizontal range provides the identity cues that are the most stable across viewpoints. The comparison of model and human observers' performance shows that the stability of horizontal cues across viewpoints uniquely predicts a significant part of human identification performance.

These results indicate that the horizontal signal in the face enables its viewpoint-tolerant representation and yield novel insight on the strategies developed by the human visual system to achieve invariant face recognition.

Individual face fixation biases generalize to inanimate objects

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Individuals have varying preferences for where they fixate on a face, with some preferring to look near the eyes and others closer to the mouth region. Previous studies have found that these biases are individually optimal for face recognition and that they generalize from the lab to the outside world. Such face fixation biases have further been associated with social cognition and associated disorders. A prevailing hypothesis postulates that these biases arise from internal face templates, which are stored in retinotopic coordinates and shifted between observers. Here, we test the alternative hypothesis that face fixation biases are domain-general. In a first experiment, participants freely viewed 700 images of static natural scenes. We analyzed the vertical landing position of more than 1.3 million fixations on faces and inanimate objects across 310 observers from three independent samples acquired at two different labs. Individual fixation biases were consistent within sessions ($r > .8$) and across sessions weeks apart ($r > .65$) for both, faces and objects. Crucially, individual fixation biases for faces and objects were also highly inter-correlated in all samples ($r > .55$), suggesting that face fixation biases are domain-general. In the second experiment, we tested the robustness of this result in a subset of 60 participants weeks to months after they took part in the first experiment. Participants performed a Saccade Recognition Task in which they had to saccade to a briefly displayed face which they then identified among a set of alternatives. We analyzed participants' saccade landing positions on these faces and correlated them with participants' individual fixation biases from the previous free viewing experiment. Saccade landing positions in the Saccade Recognition Task were significantly correlated with individual fixation biases in the first experiment for both, faces ($r = .46$) and objects ($r = .35$). We conclude that individual face fixation biases are at least in part domain-general rather than face-specific.

Evidence for Dissociable and Shared Mechanisms underlying motion-induced position shift illusions.

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Motion-induced position shifts (MIPS) are a group of visual illusions in which motion signals bias an object's position, causing the position to be misperceived. A notable MIPS is the flash-lag effect, in which a static object presented in spatiotemporal alignment with a moving object is perceived in a position behind the moving object. Previous research has typically studied MIPS individually, proposing various neural mechanisms (e.g., postdiction and extrapolation) to explain each illusion. Consequently, the extent to which shared or dissociable mechanisms underlie these phenomenologically similar illusions remains unknown. We sought to address this gap by examining individual differences in illusory magnitude for eight MIPS. During two sessions, 106 participants viewed: the flash-jump effect, Fröhlich effect, flash-drag effect, flash-grab effect, motion and luminance flash-lag effects, twinkle-goes effect, and drifting gabors. Test-retest reliability correlations showed that all illusory effects were stable across both sessions. After averaging across both sessions, correlations between all pairs of illusions were explored. Of our 28 pairwise comparisons, there were 4 statistically significant correlations. The flash-grab effect, drifting gabors, and twinkle-goes effect were all positively intercorrelated, and the Fröhlich effect and flash-drag effect were positively correlated. These positively correlated illusions may share underlying mechanisms. An exploratory factor analysis was subsequently conducted to further explore the factorial structure of MIPS. The flash-grab effect, drifting gabors, and twinkle-goes effect loaded onto a single factor, providing further evidence that a shared factor underlies these illusions. No other illusions loaded onto a shared factor. The positive correlations and factor analysis suggests that some illusions share underlying mechanisms. However, the absence of correlations for many illusions suggests that dissociable mechanisms underlie these different illusions. Overall, the present study uses an individual differences approach to demonstrate that MIPS involve both shared and dissociable mechanisms.

Is there a neural common factor for illusions?

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The source of interindividual variability in the susceptibility to visual illusions has long been a subject of debate. A series of studies has claimed that susceptibility to size illusions correlates with idiosyncrasies in surface area and population receptive field (pRF) size in early visual areas. We have previously shown that between-illusion correlations are weak, provoking the question how it is possible that illusion magnitudes correlate with neural measures but not with each other. Here, we tested 30 healthy participants in a behavioral and 3T fMRI experiment. We used pRF mapping to estimate the surface areas and pRF sizes of early visual areas V1 to V4. In a separate session outside the scanner, we measured participants' susceptibility to 13 visual illusions. We tested three illusions for which illusion magnitudes have previously been reported to correlate with V1 surface area or pRF size: the Ponzo "hallway", Ebbinghaus and Delboeuf illusions. In addition, we tested four other size illusions, as well as six control illusions, for which size is irrelevant (uniform texture, perceived orientation, or contrast illusions). As expected, the test-retest reliability of illusion magnitudes was high. We also confirmed previous findings of weak between-illusion correlations and strong correlations between variants of the same illusion. We did not find any significant correlations between illusion magnitude and visual surface areas. We also did not observe any significant correlation between illusion magnitude and pRF size. In summary, our findings fail to provide evidence of a behavioral or neural common factor for illusions.

Inter-Individual Variability of Visual Illusions: Validity and Potential of Online Experiments as a Tool for Visual Illusion Study

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Visual illusions have long been studied in psychology, revealing robust effects with small individual differences. However, the magnitudes and directions of the illusory effects can vary among individuals. This study investigated the validity and potential of online experiments as a tool for visual illusion research and explored inter-individual variability of the magnitudes of visual illusions.

Two hundred participants completed perceptual tasks examining the magnitudes of eight different visual illusions, such as brightness assimilation, simultaneous brightness contrast, Müller-Lyer illusion, Poggendorff illusion, Zöllner illusion, Watercolor illusion, Hermann Grid illusion, and scintillating grid illusion. The magnitudes were measured using the a subjective rating method for the scintillating grid illusion and cancellation/matching method for other illusions. Each illusion was presented twice in random order to assess test-retest reliability. The participants conducted the task on their own computer, following written instructions, and without any interaction with the experimenter.

The results showed stable responses within individuals, with correlation coefficients ranging from 0.44 to 0.92 between the first and second answers. Notably, some participants robustly demonstrated the opposite direction of the illusory effect in certain illusions, such as brightness assimilation and Poggendorff illusion. The within-individual correlation among different illusions was weak and unstable, which indicated independent underlying mechanisms for each illusion. Additionally, subjective sensitivity of sensory processing measured by VVIQ and HSP did not correlate with the measured magnitudes of illusions, suggesting that other factors contribute to inter-individual variability.

Our findings demonstrate the validity and potential of online experiments as a tool for visual illusion research, providing larger and more diverse samples that reveal novel aspects of illusions and their inter-individual variability.

The size-weight illusion is explained by efficient coding based on correlated natural statistics

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In our everyday experience, the sizes and weights of objects we encounter are strongly correlated. When objects are lifted, visual information about size can be combined with haptic feedback about weight, and a naive application of Bayes rule predicts that the perceived weight of larger objects should be exaggerated and smaller objects underestimated. Instead it is the smaller of two objects of equal weight that is perceived as heavier, a phenomenon termed the size-weight illusion (SWI). Previous attempts to account for this phenomenon have appealed to violation of expectations, categorization of the continuous property of object density or optimality for long-distance throwing. Here we provide a parsimonious normative explanation based on the principle of efficient coding, which dictates that stimulus properties should be encoded with a precision that depends on how frequently they are encountered in the

natural environment. We show that the precision with which human observers estimate object weight varies as a function of both weight and volume, and this relation is consistent with the estimated joint distribution of these properties among everyday objects. Recent theoretical work has shown that optimal inference about features with a gradient of discriminability leads to perceptual biases that may counteract and even overpower the usual Bayesian attraction to the prior. We show that participants' observed "anti-Bayesian" biases (the SWI) are consistent with Bayesian inference when taking into account the gradients of precision induced by efficient coding. Related phenomena such as the material-weight illusion can be accounted for by the same principles. These results resolve a century-old paradox of multisensory perception.

Painting, Architecture, Space – Eye and body movements in VR disambiguate illusions.

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The mutual interest between arts and visual science has a tradition, to which ECVP made large contributions. This cross-disciplinary interaction can reach a new level using new technology, like VR studies with eye tracking enabled headsets, that can shed new light on difficult and exciting questions about the experience of artwork in the context of active exploration. We previously constructed VR environments that can bring artworks into the lab to study observers' exploration behaviour, including eye movements, that can be compared to behaviour in the real museum or gallery (e.g. Gulhan, Durant & Zanker, 2021 Scientific Reports 11:18913). Here we report eye movements recorded in a VR reconstruction of a historical monument - the Carafa Chapel (Santa Maria sopra Minerva in Rome, Filippina Lippi, 1493) - which was first presented at ECVP 2022.

This renaissance 'Gesamptkunstwerk' is somewhat unique by mixing frescos, painted panels, frames and sculptures, and architectural columns, which create a dazzling environment of illusory and real objects in space. The interaction between real and illusory elements incorporated in a large, but confined space will be demonstrated for. In the lab, issues with access, illumination, and interferences by other observers are minimised, and participants can focus on the particular task – in the present case whether a column or frame element is real or illusory. The eye movement patterns recorded from the VR environment show a focus on vertical and horizontal edges that appear to indicate spatial structures that can be convex or concave – drawing in the attention of our initial participants, whilst the physical contours between the orthogonal walls of the chapel attract less interest.

Measuring the "rocking line" illusion.

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Recently, we introduced a new motion effect called the "rocking line" illusion (RLI; Thornton & Todorović, 2023). When a single target rectangle moves horizontally through the midline of a static checkerboard pattern, its perceived path is strongly perturbed so that it appears to rock systematically around its own center. This dynamic variant of well-known polarity-dependent orientation illusions (Todorović, 2021), is probably closely related to the footstep/inchworm illusion (Anstis, 2001) and possibly the slalom illusion (Cesaro and Agostini, 1998). The RLI is robust, in the sense that all observers experience the effect, but has a strong dependence on overall display scale as well as the checkerboard frequency and contrast. The current work has two goals. First, to introduce a freely-available online resource where the illusion can be experienced and relevant parameters manipulated. Second, to describe a method for objectively quantifying the magnitude of the orientation shifts experienced during motion. To measure the RLI, we created a variant in which the target object remains fixed at the display center, while the checkerboard scrolls across the screen. The induced motion causes the physically horizontal target object to rock in place, and its fixed location makes it easy to compare to an identical adjustment probe. The probe is positioned directly below the target object, and is controlled by the observer, using a single parameter: angle of deflection. This parameter is used to drive the apparent motion of the probe, with the frequency of angular update locked to the periodicity of the scrolling background. A phenomenal match between the rocking target and apparent motion probe is easy to achieve and is surprisingly compelling. In summary, we believe the RLI, with its strong dependence on scale, is a useful tool for exploring the spatial and temporal mechanisms that underly the perception of orientation in dynamic contexts.

Sound frequencies modulate afterimage saturation

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Many studies showed that there are strong analogies between the nature of synaesthetic experiences and those reported by non-synaesthetes in imagery, matching tasks or crossmodal

interference paradigms suggesting the existence of common processes between synaesthetic perception and audio-visual processing of non-synaesthetes. In the thirties, Zietz (1931) and Werner (1934) were the first to show that a sound presented simultaneously with an afterimage can affect afterimage appearance in non-synaesthetes. By asking subjects to verbally describe the temporal evolution of afterimages, they reported that the colours of afterimages "disintegrate" with low frequency sound and "concentrate" with a high frequency sound. By using a new instrumental method, we systematically investigated this phenomenon. After being exposed to the stimulus colour (blue, red, green, yellow), subjects were asked to adjust a cursor to temporally modulate afterimages saturation while listening a sound having different frequencies (low or high). The afterimage induced by the yellow stimulus is the most affected by sounds. Subjects perceive a faster colour temporal desaturation while exposed to low frequency sounds and a slower colour temporal desaturation while exposed to high frequency sounds. In contrast, the recordings concerning the stimulus with blue colour show a sudden drop, i.e. an extremely fast temporal desaturation of the colour regardless of the frequency used. These data are coherent with the crossmodal correspondences between both pitch and loudness in audition and lightness and brightness in vision reported in the literature.

The honeycomb illusion: Peripheral vision of contours, unlike that of objects, is refractory to predictions, extrapolation and memory effects.

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Visual acuity decreases with eccentricity, but the differences between central and peripheral vision are almost absent in our experience of the visual world. In particular, we experience uniform extended textures as uniform and objects retain shape and colour at any location. Perception of complex scenes has therefore been described as a "grand Illusion". Various mechanisms play a role, including the fact that the system can rely on predictions based on prior assumptions (for instance that textures are uniform) or experience (from previous fixations). On the other hand, there are known examples where priors do not affect amodal completion (Kanizsa, 1980). We studied extended textures created with a square grid and some additional lines (Bertamini et al., 2016). These lines are visible/invisible depending on whether they are located at the corners of the grid, or separated from the grid (control condition). In the first case the texture appears non uniform (Honeycomb illusion, HI). Participants judged the extend of the texture with lines, and we compared cases in which the central region was informative (same) or non-informative (different). We also tested sensitivity to shape information in the periphery in a forced-choice task. The drop in sensitivity (quantified as d') matched the size of the region in which lines were perceived in the HI, even in the control case where lines were seen over the whole texture. We conclude that mechanisms that control perception of contours operate differently in the periphery, and override prior expectations, including that of uniformity. Conversely, when elements are detected in the periphery we assign to them properties based on central vision, and are unaware that these shapes cannot be identified correctly when the task requires such discrimination.

Deep reconciliation of categorical colour perception

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We perceive colours categorically. Our perceptual system separates a continuous space into distinct categories. The most prominent example is the rainbow, there are no discontinuities in its colour spectrum, yet we see discrete bands. The underlying reason, particularly the role of language, has spawned a heated debate between universalists and relativists. We reconcile these two explanations by studying vision-language and pure-vision deep neural networks (DNN). The results of our odd-one-out experiments show that pure-vision models (e.g., ImageNet object recognition networks) explain 85% of human data. In turn, suggesting a large part of our categorical colour perception is purely driven by visual signals. The remaining 15% is explained with vision-language models (e.g., CLIP text-image matching networks) even when tested without their language module. In turn, suggesting colour categories is a free-from-language representation, yet linguistic colour terms have influenced its development. We investigated whether colour categories emerge in all pure-vision models by studying Taskonomy networks trained on 24 visual tasks. Human-like colour categories appear only in less than half of those models, namely, networks trained on semantic (e.g., image segmentation, object recognition, and scene classification) or 3D tasks (e.g., shade from shaping, surface normal prediction, and depth estimation). Our results show low-level tasks (e.g., autoencoding and denoising) never obtain human-like colour categories. It also matters whether a network is trained on 2- or 3-dimensional outputs for the same perceptual task. Networks trained on 3D tasks of edge and keypoint detection obtain human-like colour categories but not their corresponding 2D networks. Overall, our findings provide evidence for the utility of categorical colour representation in several visual tasks but also indicating a portion of categorical colour perception can only be explained by the language component, reconciling both universal and relative theories.

Swiping colors in virtual reality: How stable are color category borders?

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Previous work on color categories has shown categorical facilitation (e.g., quicker responses and higher accuracy) for tasks involving colors that cross category borders, compared to colors in the same category. We adopted a paradigm from animal learning to investigate the stability of these category borders in humans. In a VR videogame task, observers held a colored saber in each hand, and were shown cubes with a colored stripe, which approached from a distance in succession. Observers were instructed to swipe the cubes with the saber that best matched the colored stripe. Hues from the green-blue and pink-purple color ranges were tested. In a baseline block, observers were tested on a predetermined set of colors, where three of the hues tested were ambiguous. Subsequent blocks shifted the range of colors tested in the direction of one of the endpoints. We fit the data with a psychometric function, and the point of subject equality (PSE) determined the location of the category border. If observers' responses were absolutely stable, there would be no difference between the baseline PSE, and the shifted PSEs. Alternatively, observers' responses could show a range effect; the PSE would shift in the same direction as the shift in the colors tested. Our results show that observers exhibit a shift of their category borders in the direction of the color shift, but the shift falls short of a complete adaptation to the changes in the range of colors. This work suggests color category borders are not perfectly stable, and this should be taken into consideration when probing categorical facilitation effects in color.

Acknowledgments: Alexander von Humboldt Fellowship to AMA and Deutsche Forschungsgemeinschaft SFB TRR 135 (project number 222641018) TP C2

Colour discrimination in COVID-19 survivors

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Post-COVID-19, recorded were various ophthalmological symptoms, accompanied by photophobia, decreased visual acuity etc. We hypothesized that colour vision may be affected, too. We assessed colour discrimination using the Farnsworth-Munsell 100 Hue test (FM-100) in individuals, who have had COVID-19 (N=77; 18–68 years). Their recovery period, prior to the testing, ranged between 21–871 days. The total error score (TES) indicated normal colour discrimination in 46 participants. However, a considerable number of participants revealed mild blue-yellow (B-Y) impairment (N=29) or moderate diffuse defect, i.e. blue-yellow and red-green (N=2). √TES negatively correlated with the recovery time lapse: on average, colour discrimination reverted to normal by ca. 450th recovery day. Various measures of partial error scores (√PES) provided evidence that, regardless of the post-COVID recovery time lapse, errors along the B–Y axis prevailed. The impact was greater on discrimination in the green–blue gamut than in red–yellow; in addition, √PES pointed out to vision 'mesopization', i.e. likened to normal trichromats' performance at low luminance levels. Furthermore, vector analysis (Vingrys & King-Smith, 1988) showed that for 41 (out of 77) observers the C-index (severity) exceeded the cut-off measure (1.12) estimated for Caucasian healthy normal trichromats (Dain et al., 2004). In five of these, the S-index (polarity) and the Angle of confusion indicated tritan loss, including one relatively severe case, whose indices were comparable to those for a congenital tritanope or a patient with optic atrophy reported earlier. Overall, in ca. 60% of COVID-19 survivors the results point out to Type III acquired colour discrimination loss, predominantly mild and, in a few cases, moderate, characteristic of retinal disorders and vascular disease (Pokorny & Smith, 1986). Conceivably, coronavirus infection caused (reversible) hypoperfusion (reduced vascular supply) at the retinal and/or post-retinal stages of the visual system having affected neural mechanisms of colour discrimination.

[Russian Science Foundation (grant No. 22-18-00407)]

COLOUR MEMORY STRATEGIES IN DALTONISM

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Color perception helps us remember and recognize both natural and artificial objects. This ability is compromised in individuals with color vision deficiency (CVD). Adapting colors on the screen allows better discrimination in CVDs. Previously we showed that filtered colors bring CVDs closer to the controls in perceptual and memory tasks, while now we focus on CVDs's memory strategies with various colors (nonproblematic, problematic, filtered).

Two color pairs (from the opposite side of the gamut plane, Euclidean distance: ΔE = 0.2) were chosen from two pseudo-

isochromatic lines and daltonised (enhancing the red-green contrast in the direction of isochromatic line, or enhancing the blue-yellow contrast perpendicular to it, ΔE=1.0). Nonproblematic color pairs were created with one color from the problematic pair and the other perpendicular to its pseudo-isochromatic line (again ΔE=0.2 or 1.0).

Seven deuteranomalous (1 female, ASage = 28.3) performed a dual task. In the primary task, a color was briefly shown and participants had to match it with one of the two colors presented after ISI=1.5s. During that ISI, there was either no interference, or participants performed a secondary verbal or visual task.

The time needed for matching of problematic and nonproblematic colours significantly differed only when colors were unfiltered ($F(2,12) = 7.28$; $p=.008$; $\eta2=.55$). This confirms our previous findings that filtering enhance the performance of the visual working memory in the same way as in perception. More interestingly, there were significant differences in how interference impacted RTs depending on the color pair - while matching of problematic colors was slowed only by the visual interference, the matching of nonproblematic colors was equally affected by both types of interference ($F(2,12)=6.48$; $p =.01$; $\eta2=.52$). These results indicate different memory strategies in CVDs, suggesting that they use verbal strategy only for the part of the visible spectrum not affected by the condition.

Adult and children colour selections for emotion terms: The importance of chroma and hue

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People easily associate colours with emotions with such pairings differing by valence (e.g., lighter colours are judged as more positive). Yet, pairings are comparable for actual colours and colour terms, indicating that conceptual knowledge of such pairings is sufficient. To study the emergence of colour-emotion pairings, we compared colour selections for 20 emotion terms provided by 6-7-year-old children (n = 33), 11–12-year-old children (n = 30), and 18-32-year-old adults (n = 63). All participants used a colour picker to select colours best matching each emotion term. To compare colour choices, we converted the RGB values of each colour to CIE LCh values, assuming standard viewing conditions (gamma 2.2). We grouped emotions by valence, either positive or negative. Hues differed for positive emotions, $\chi2(14) = 119.92$, $p < .001$, with younger children selecting fewer red and green-blue hues, and adults selecting fewer yellow hues. For negative emotions, hues also differed, $\chi2(14) = 175.21$, $p < .001$, with adults choosing more purple hues, but fewer yellow-green and green hues than the children groups. Chroma differed for positive emotions $F(2,119) = 27.8$, $p < .001$, with adults choosing more chromatic colours. For negative emotions, chroma did not differ $F(2,119) = 2.13$, $p = .124$, between age groups. Lightness also did not differ between age groups for positive, $F(2,119) = 58.3$, $p = .903$, or negative emotions, $F(2,119) = 1.93$, $p = .149$. We conclude that hue and chroma underlie developmental changes in colour-emotion pairings, and by inference their conceptual construction. These might emerge with the acquisition of cultural and societal knowledge (i.e., red and love metaphor). To pinpoint the trajectory of colour-emotion pairing acquisition, studies should test older children and adults, ideally, with a longitudinal design.

Transfer of learning and causal reorganization of brain connectivity through rapid mental-map training

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Mental or spatial cognitive maps are fundamentally important, particularly when vision is lost and only tactile and audio inputs are available, as in blind navigation. We translated the rapid and efficient Cognitive-Kinesthetic Training (based on blind-memory-drawing, initially developed for the manual domain; Likova, 2012) to the navigation domain.

Methods: Before the Cognitive-Kinesthetic Training (2 hours/day for 5 days), after the training, and 3-6 months later, we ran fMRI (3T Siemens Prisma) in blind participants on a suite of navigation tasks, together with standardized behavioral measures for spatial cognition. The fMRI tasks included: Drawing-from-memory of a just-explored multi-intersection tactile map (30 s); Planning from that spatial mental-map in memory the shortest path between two newly-specified locations on the map (10 s); Drawing that mentally-determined shortest path (10 s).

Results and Conclusions: Spatial mental-mapping, memory and spatiomotor coordination were significantly improved by Cognitive-Kinesthetic training. Transfer of learning: Moreover, sustainable transfer of the Cognitive-Kinesthetic training effects from micro-to-macro navigation were found, as well as to untrained spatio-cognitive abilities. This confirms the power of C-K as an active instigator of core spatio-cognitive improvements, operating simultaneously across neural subsystems, fulfilling the demand for wide-spectrum rehabilitation through a single-training-method. Brain reorganization: Pre/post training, Granger-Causal Connectivity Analysis investigated both

congruent and inverse Granger-Causal influences. Massive connectivity reorganization of the frontal-hippocampal-insular-retrosplenial-V1 cortical network took place. Remarkably, the (blind) primary visual cortex V1, implicated as the neural implementation of the (amodal) memory 'sketchpad', actively engaged in both top-down and bottom-up causal interactions within this network. These results establish the profound cognitive and brain reorganization by this brief mental-map-based navigation training, showing that such changes do not take a lifetime of driving a taxicab, for example, and demonstrating the power of a multidisciplinary approach incorporating art/drawing, behavioral and neuroscience methodologies to drive much-needed plasticity in the adult brain.

Extensive visual training in adulthood reduces an implicit neural marker of the face inversion effect

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Face identity recognition in humans is supported by specialized neural processes whose function is substantially impaired when simply turning a face upside-down: the Face Inversion Effect (FIE) (Yin, 1969, https://doi.org/10.1037/h0027474). Inverted faces provide a strong test for whether experience in adulthood can influence face-specific processes because they contain the same visual information as upright faces for which we already have saturated experience, and inverted faces disrupt the biological constraints present at birth for preferential looking (i.e., fewer features in the bottom part than the top part of the stimulus). However, currently, little is known about the plasticity of the neural processes involved in this FIE at adulthood. Here we investigate if extensive training (2 weeks,~15 hr) in young adults discriminating a large set of unfamiliar inverted faces can reduce the FIE for a set of entirely novel faces. 28 adult observers were trained to individuate 30 inverted face identities presented under different depth-rotated views. Following training, we replicate previous behavioral reports of a significant reduction in the behavioral FIE as measured with a challenging four-alternative delayed-match-to-sample task for individual faces across depth-rotated views (Laguesse et al., 2012, https://pubmed.ncbi.nlm.nih.gov/23019119/). Most importantly, using EEG together with a validated frequency tagging approach to isolate face individuation neural responses (Rossion et al., 2020, https://onlinelibrary.wiley.com/doi/10.1111/ejn.14865), we observe a reduction in the neural FIE at the expected occipito-temporal channels. Moreover, the reduction of the neural FIE correlates with the reduction of the behavioral FIE at the individual participant level (r=0.46). The reduction in the neural FIE is not observed in a concurrently frequency tagged control signal that peaks at the more posterior medial occipital channels and reflect general visual responses. Overall, we provide novel evidence suggesting a substantial degree of plasticity in face-specific processes that are key for face identity recognition in the adult human brain.

Glutamatergic processing in human pulvinar supports predictive structure learning

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In our everyday interactions with the environment, we are bombarded by dynamically changing information. Learning improves the brain's ability to parse and interpret complex sequences of events that may initially appear incomprehensible. Yet, our understanding of the brain mechanisms that support our ability to extract temporal structure and predict future events remains limited. Here, we investigate the neurochemical mechanisms that support this predictive structure learning. Using magnetic resonance spectroscopy (MRS) in the 7T, we measured neurotransmitters (i.e., glutamate, GABA) that are known to be involved in visual processing and learning, while participants performed a structure learning task. In particular, participants were presented with sequences comprising oriented gratings and were asked to predict the orientation of the upcoming grating following each sequence. The structure of the sequences was governed by first-order Markov models (i.e. the probability of each orientation depended on the preceding grating). We conducted MRS measurements in the thalamus (pulvinar) that is known to be involved in temporal processing before and after training in the task (2 scanning sessions in consecutive days). Our results showed significant decrease in glutamate (referenced to creatine or water and corrected for tissue composition) after training. Further, this decrease in glutamate correlated significantly with improved behavioral performance in structure learning, suggesting that the pulvinar is involved at earlier stages of learning. Our results suggest a key role for thalamic glutamatergic processing in learning to extract probabilistic temporal structures and predict future events.

Spatial Cognition and Intervention-Induced Changes in White Matter Integrity: The Case of Dancers

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Identifying how dance improves cognitive processing has major implications for understanding intervention strategies for neurorehabilitation and healthy aging. This study aims to provide evidence and open new avenues for investigating how the white matter (WM) integrity of pathways in the healthy brain mediates the effect of dance training on spatial cognition. To this aim, 126 healthy adult participants with different levels of dance experience – experts, non-experts, and non-dancers - underwent MRI scans and completed a virtual reality (VR) spatial cognition task at the beginning of the study and one year later. During the twelve months, some participants completed dance training while others did not, resulting in a 3 (Level: expert, non-expert, non-dancers) X 2 (dance training, no dance training) design with matched samples. Findings from the VR task demonstrated that experts were significantly more accurate than non-experts and non-dancers at the first assessment. After one year of dance training, non-experts were as accurate as experts and significantly more accurate than non-dancers, suggesting that dance experience can increase spatial processing ability in non-dancers. Before dance training, experts had lower fractional anisotropy, indicating lower WM integrity, than non-dancers in two WM tracts: the corticospinal tract, which is related to motor processing, and the inferior longitudinal fasciculus, which is related to visual processing. We are now looking into the diffusion and behavioral results to assess whether intervention-induced changes in the white matter are related to alterations in spatial cognition processing.

Acknowledgments: This research is funded by the Cyprus Research and Innovation Foundation under the 2018 Excellence Hubs Calls, RPF No EXCELLENCE/1216/0034, and the European Structural Funds.

Behavioral performance improvement in visuomotor learning correlates with functional and microstructural brain changes

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A better understanding of practice-induced functional and structural changes in our brains can help us design

more effective learning environments that provide better outcomes. Although there is growing evidence from human neuroimaging that experience-dependent brain plasticity is expressed in measurable brain changes that

are correlated with behavioral performance, the relationship between behavioral performance and structural

or functional brain changes, and particularly the time course of these changes, is not well characterized.

To understand the link between neuroplastic changes and behavioural performance, 15 healthy participants in

this study followed a systematic eye movement training program for 30 min daily at home, 5 days a week and

for 6 consecutive weeks. Behavioral performance statistics and eye tracking data were captured throughout the

training period to evaluate learning outcomes. Imaging data (DTI and fMRI) were collected at baseline, after two and six weeks of continuous training, and four weeks after training ended.

Participants showed significant improvements in behavioral performance (faster task completion time, lower

fixation number and fixation duration).

Spatially overlapping reductions in microstructural diffusivity measures (MD, AD and RD) and functional activation increases (BOLD signal) were observed in two main areas: extrastriate visual cortex (V3d) and the frontal

part of the cerebellum/Fastigial Oculomotor Region (FOR), which are both involved in visual processing. An

increase of functional activity was also recorded in the right frontal eye field.

Behavioral, structural and functional changes were correlated. Microstructural change is a better predictor for

long-term behavioral change than functional activation is, whereas the latter is superior in predicting instantaneous performance. Structural and functional measures at week 2 of the training program also predict performance at week 6 and 10, which suggests that imaging data at an early stage of training may be useful in

optimizing practice environments or rehabilitative training programs.

Combining multi-session tACS with reading acceleration training can ameliorate self-paced reading, oculomotor control, working memory and neural dynamics of motion perception in dyslexia

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Developmental dyslexia (DD) affects about 10% of individuals and is associated with both phonological and visual deficits. Visual deficits are attributed to dysfunctions in the magnocellular-dorsal (M-D) stream, which has a critical role in guiding ventral stream areas activity where letters/words identity is extracted. Oscillatory activity in the beta band (15-30 Hz) is increasingly associated with the M-D functionality, and the application of beta-band transcranial alternating current stimulation (tACS) to parietal areas ameliorates the segmentation of letters in crowded displays. Therefore, we hypothesized that combining a reading acceleration training with multi-session tACS in participants with DD could ameliorate not only reading performance, but also the M-D stream functionality and potentially other sensory-motor and cognitive domains that are impaired in DD.

Adults with DD were enrolled in a randomized single-blind clinical trial where they received beta-band tACS over left and right parietal sites or a sham (placebo) stimulation. Both groups underwent a reading acceleration training composed of 12 sessions where written sentences were presented on the screen and faded progressively faster based on performance. Throughout the training sessions, we recorded changes in self-paced reading and gaze data. Before and after the training, we also administered standardized cognitive tests, including the digit span, and recorded EEG during a coherent motion discrimination task to probe the M-D functionality. Results show that both groups ameliorate their reading skills over the course of the training. Importantly, in the tACS group we observed: i) a stronger reduction of regressive fixations and saccades; ii) an increased amplitude of the N2 ERP component elicited by coherent motion stimuli, and iii) an improvement in digit span. Overall, our findings suggest the efficacy of multisession tACS in improving outcomes of reading trainings and in ameliorating some of the core perceptual, oculomotor and cognitive deficits associated with reading disorders.

Contributions of retrospective attentional control to visual working memory performance: insights from the developing cognitive system

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Visual working memory (VWM) capacity is highly limited, yet this limit changes over development. One prominent account aiming to explain improvements in VWM performance across development proposes a simple increase in storage capacity. However, recent findings have shown that the developing ability to use retrospective attentional control to enhance maintenance is important for understanding developmental improvements in VWM. Critically, changes in retrospective attentional control are not the endpoint to understanding developmental differences in VWM, rather additional factors seem to mediate the interaction between the two cognitive mechanisms. Here, I will present data from a series of complementary experiments investigating attentional control and VWM dynamics, as well as the factors that influence their interplay, in children and adults. Findings from these studies collectively indicate how attentional control facilitates maintenance in VWM and reveal the mechanisms driving improvements in VWM limits from childhood into adulthood.

Delayed selection of motor but not visual information with higher working memory load

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Visual working memory allows us to use past sensory information to guide upcoming (potential) behavior. How the brain selects multiple sensory representations and potential action plans remains poorly understood. Specifically, it is unclear how the dynamics of visual and motor selection depend on memory load. It is generally found that reaction times in working memory tasks are slower when we select among more content in memory (i.e., with higher memory load). However, it is unclear whether this is due to an increase in the time needed to access the relevant sensory representations, lower preparedness to act upon them, or a combination of both. To address this question, we designed a visual-motor working memory task with a memory load manipulation (two/four items). In this task, memorized visual tilt was linked to specific manual actions, enabling us to independently track the selection of visual (item location) and motor (required response hand) information from the EEG signal. We used time-frequency and multivariate

decoding analyses to compare selection dynamics between the memory load conditions. These revealed that the latency of visual selection does not depend on memory load, while motor selection is delayed with higher memory load. These results demonstrate how the observed slower reaction times with higher memory load may not be due to an increase in the time needed to access the relevant sensory content, but rather to being less prepared to act upon this content.

Predictive Role of Individual Visual Working Memory Capacity in the Aesthetic Appreciation of Chinese Ink Paintings

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Aesthetic appreciation is shaped not solely by intrinsic properties of the artwork (e.g., visual complexity), but also by extrinsic factors related to the observers, such as the visual working memory capacity that enables real-time storage and manipulation of visual information. Here, we addressed the predictive role of both intrinsic and extrinsic factors in aesthetic appreciation in the Chinese context.

Thirty Chinese college students (53% females; age range: 17–24 years) participated in our study. We measured their visual working memory capacity with the Visual-Object Working Memory task (Sherman et al., 2015) in which participants need to sequentially encode, maintain, and decide if the current visual pattern was the same as the one presented 2 trials ago. We then presented them with twenty Chinese landscape ink paintings created in the period between the 19th and 21st century and asked them to indicate their aesthetic preference and visual complexity judgment for each painting along a 6-point Likert scale. The objective complexity evaluation of each painting was quantified with Spectral slop, Fractal dimension and Entropy (Mather, 2020).

In contrast to the absence of association between visual working memory capacity and aesthetic preference in Sherman et al. (2015), our results revealed a significant positive correlation between the d' in the Visual-Object Working Memory task and aesthetic preference score, suggesting that an individual's visual working memory capacity is predictive of the extent to which they enjoy the painting of their own culture. However, nor did the human subjective or the algorithm-derived objective visual complexity evaluation associate with the aesthetic preference in our data despite that these two types of complexity evaluation showed consistent pattern with each other. These findings offer novel insights into the compatibility between viewer and artwork in terms of culture in the aesthetic appreciation.

Measuring effects of cognitive load on visual capacity in virtual and augmented reality environments

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We present the results of a series of studies that evaluate the extent to which various cognitive load tasks affect participants' ability to integrate spatially disparate elements presented via virtually reality (Oculus Rift) and augmented reality (HoloLens 2) HMD devices. We employed a Gabor averaging paradigm requiring participants to make a binary decision (left vs right) regarding some global featural property of the local Gabor elements (orientation, binocular disparity, colour or their conjunctions) via the HMD. The number of Gabor elements (set-size) varied across trials. The distribution of the relevant Gabor feature was normally distributed with the centroid fixed at ±5% feature units from a nominal centre point in the relevant feature domain (degrees, meters, RGB) with a standard deviation of 20%. Averaging performance was evaluated using a gamified first-person shooter task involving two visually identical virtual agents, each located ten meters (in virtual space in VR or via screens in the AR version) to the left and to the right of a virtual post positioned twenty meters from the participant. On each trial one agent was randomly assigned to be an 'enemy' and the other a 'friendly'. The participants' task was to shoot the enemy using a motion-tracked gun before being shot by this agent, which occurred on average 3 seconds after the presentation of the Gabor array. The enemy agent was uniquely signified by the relevant global featural property of the Gabor array. Shooting accuracy decreased and reaction times increased monotonically and asymptotically with increasing Gabor set size. Visual capacity was indexed by both the rate and the asymptotic limits of this performance degradation. Cognitive load was applied using an n-back letter paradigm (visual and auditory; n-1, 2 and 3) as well as a verbal shadowing arithmetic task in separate blocks. Results to date indicate that whilst Gabor averaging-related shooting performance deteriorated overall with increasing cognitive load, visual capacity is not significantly affected.

Top-down Attentional Capture by Affective Scenes Occurs Independent of Competing Visual Working Memory Load

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Recent evidence has suggested that attentional capture by peripheral real-world scenes can occur when they are congruent with an individual's current top-down attentional set, and that this could potentially explain the heightened attentional capture by negative affective scenes. It is not clear, however, whether this top-down conceptual capture requires the active maintenance of the conceptually relevant features in Visual Working Memory (VWM), or whether it occurs through a more implicit mechanism. To test this, a series of three pre-registered experiments were conducted (N = 25, 26, 24) involving a Rapid Serial Visual Presentation task (RSVP). Participants were instructed to search for a centrally presented target in the RSVP, either from an affective category (i.e., people injured) or a neutral category (i.e., people reading) in separate blocks, whilst ignoring peripheral irrelevant distractors depicting affective scenes of injury or neutral scenes. VWM load was manipulated through the performance of a concurrent VWM change detection task, requiring participants to store images of real-world objects in VWM. Across experiments, peripheral affective scenes only disrupted the detection of centrally presented targets when they were congruent with the current top-down attentional set. Interestingly, Experiment 1 revealed only moderate evidence of attenuation of this top-down driven capture by high VWM load (3 objects stored in VWM) relative to a no VWM load condition. Further, in Experiment 2 and 3, there was no evidence of attenuation under concurrent high VWM load, relative to low VWM load (1 object), or when the VWM task was performed prior to the RSVP search task, rather than concurrently. The results suggest that rapid scene perception of task-irrelevant affective stimuli and attentional capture by these scenes can occur largely independent of VWM, but only when congruent with the current attentional set. The possible implicit top-down mechanisms of this attentional capture are discussed.

Neural enhancement in vision

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In natural scenes, faint and briefly presented stimuli often go unnoticed. When such stimuli are important for a task, neural responses to these stimuli need to be amplified. Here, using evoked-related potentials (ERPs), we show evidence for such neural amplifications. We presented a vernier, i.e., two vertical bars with a slight horizontal offset, as the target. Participants had to discriminate whether the lower bar was offset to the left or right.

First, we compared the ERPs when the vernier was task-relevant versus when it was task-irrelevant. When the vernier was task-relevant, an occipital frontocentral topography was elicited at ~200 ms after the stimulus onset. In the task-irrelevant condition, we found the same topography but with strongly reduced amplitudes and durations. Hence, attention to the target amplifies neural responses. Second, we tested the same participants in a backward masking task, where the vernier was followed by a mask. As expected, performance strongly deteriorated for short inter-stimulus intervals. The neural responses follow the performance. Hence, stronger masking reduces neural responses. Interestingly, the same topography was observed in both experiments, suggesting similar brain processing.

We propose that target enhancement by recurrent processing explains these results. The weak neural responses to the target, provoked either by the mask or task irrelevance, may be amplified by attention, which stabilizes and enhances the neural responses. We show that this target-enhancement mechanism is deficient in schizophrenia patients.

Resting-state neural correlates of visual Gestalt experience.

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Subjective perceptual experience is influenced not only by bottom-up sensory information and experience-based top-down processes, but also by an individual's current brain state. Specifically, a previous study found increased prestimulus insula and intraparietal sulcus (IPS) activity before participants perceived an illusory Gestalt (global) compared to the non-illusory (local) interpretation of a bistable stimulus. That study provided only a snapshot of the prestimulus brain state that favors the illusory interpretation. In the current study, we tested whether areas that differentiate between the illusory and non-illusory perception immediately before stimulus onset, are also associated with an individual's general tendency to perceive them, which remains stable over time. We examined individual differences in task-free functional connectivity of insula and IPS and related them to differences in the individuals' duration of the two stimulus interpretations. We found stronger connectivity of the IPS with areas of the default mode and visual networks to be associated with shorter local perceptual phases, i.e., a faster switch to the illusory percept. We also observed an inverse effect for insula connectivity with the early visual cortex. Our findings suggest an important role of the IPS and insula interactions with nodes of key intrinsic networks in forming a perceptual tendency towards illusory Gestalt perception.

The BTPI: A battery measuring susceptibility to visual illusions

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The study of visual illusions is an effective way to investigate the mechanisms of perception. Unlike other perceptual domains that have established tools for measuring individual differences, there are currently no such tools for measuring susceptibility to visual illusions. Here, we introduce the BTPI (Ben-Gurion University Test for Perceptual Illusions), an online tool designed to measure susceptibility, as well as perceptual resolution through the just noticeable difference (JND) in three size illusions - the Ponzo, Ebbinghaus, and height-width illusion. We validated the battery in self-paced and fixed-duration presentation conditions. The results revealed high test-retest reliability scores for both susceptibility and JND within each illusion, as well as some evidence for cross-illusion correlations in both measures. In addition, larger JNDs were associated with higher susceptibility to illusory effects. We also demonstrate the applicability of the BTPI by examining potential age-related in adults (between 20 and 80 years). The results showed different patterns of age-related changes in each illusion. The BTPI is freely available online for research use.

An Intuitive Physics Approach to the Water-Level Task using Augmented Reality

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The classic Water-Level Task (WLT) asks subjects to draw the water line in a half-full tilted container. Studies have shown that, on average, about 40% of adults do not draw the correct horizontal lines. Most studies of adult performance on the WLT have viewed it as a test of spatial cognition; however, it can also be regarded as an Intuitive Physics problem. If so, performance should improve under realistic, dynamic conditions.

To assess this, we compared participants' performance on the traditional WLT and in an Augmented Reality (AR) environment (using a Hololens2 device), which allowed for interaction with virtual containers half-full of water. The traditional WLT consisted of 16 online water-level drawing trials. Out of 118 undergraduate student participants, 36% drew horizontal lines (within 15 degrees) on one or fewer trials (low-scoring), and 32% drew horizontal lines on 13 or more trials (high-scoring). Seventeen low-scoring and 18 high-scoring participants subsequently took part in the AR test. We used simple water-in-container simulations and asked participants to interact with two simultaneously presented half-full containers and choose which water simulation looked more natural. In at least one of the two simulations, the water surface's stationary state was not always level but tilted as the container tilted. We found a significant correlation between participants' performance in the traditional and AR tests. However, participants found the AR simulations created to resemble their 2D water lines unrealistic. This result suggests that participants used different perceptual and cognitive processes for judging water orientation in the two scenarios. Additionally, even high-scoring participants did not immediately find anomalous AR simulations less natural, suggesting their knowledge did not directly affect their perception. Finally, contrary to our hypothesis that people implicitly encode the physics of the WLT, low-scoring participants were susceptible to errors even in a more realistic environment.

The shortened line segments illusion

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We present a new visual illusion of line shortening that was a prize winner at the 12th Visual and Auditory Illusion Contest in Japan. In the test sequence, 12 parallel lines are spaced evenly and orthogonally to the lines' orientation. This sequence is interleaved by an inducing set of parallel lines where each position has two collinear lines separated by a gap of 1/8 the lines' length. All line segments have the same physical length. The combined pattern alternates between single (test) and double (inducing) lines. The lengths of the single test lines appear shortened. This illusion is weaker when the line segments are rotated relative to the orientation of the line joining their centers, so that the inducing double lines are no longer collinear. Therefore, the illusion may arise from the grouping of the inducing lines when they are collinear. In this case they may act as long single lines producing a size contrast on the middle lines.

The Helmholtz square is immune to changes in visual angle, aspect ratio, and pattern density

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In 1867, von Helmholtz reported that a square patch with black and white stripes appears elongated perpendicular to the orientation of the stripes. For example, a vertically striped square appears wider but lower than a horizontally striped square. A few years earlier, Oppel and Kundt had reported that a horizontal distance in the frontoparallel plane appears longer when divided by small vertical lines. For the Oppel-Kundt-illusion, it has been shown that the size of the perceived elongation depends on the visual angle of the distance and the density of the dividing lines. In the present study, we investigated whether the size of the Helmholtz-square illusion also depends on the visual angle and the density of the stripe pattern. In addition, we

investigated whether the Helmholtz-square illusion is limited to squares or can be extended to non-square rectangles. For this purpose, we conducted an experiment in which we varied the retinal size (0.6° to 10.5° visual angle), aspect ratio (1:1, 1.5:1, or 1:1.5), stripe orientation (horizontal, vertical), and stripe density (0.7 to 2.6 cycles per degree of visual angle) in a fully crossed repeated-measures design. In each trial, a black-and-white striped comparison rectangle and a solid gray standard square were presented on a high-resolution large-scale computer monitor. The observer's task was to estimate the width or height of the striped rectangle in units of the standard square. Each of the 25 participants performed 360 width and 360 height estimates, yielding a total of 720 trails per participant. Our results show that the Helmholtz-square illusion remains robust across manipulations of visual angle, stripe density, and aspect ratio. In addition, we found an additive effect of stripe density, in the sense that higher stripe densities increased the perceived width and height of the comparison rectangle, independent of stripe orientation.

Perisaccadic perception of continuous flicker: spatial and temporal aspects

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When an image is displaced on the retina during saccadic eye movements the visual system must maintain perceptual space constancy. However, when the flickering light is presented during the saccade, the visual position of a spot of light is perceptually mislocalized and temporal light artefact, known as the phantom array of lights, is perceived. We investigated spatial and temporal aspects of the perception of flickering chromatic light. The flicker frequency was varied from 50 Hz to 5 kHz. The subjects were instructed to saccade in the dim room across a point light source flashing on and off at various frequencies. Then they were asked to indicate the beginning and end of the phantom array and to count the number of dots or dashes they perceive in the phantom array. In the first experiment, red, green or blue LEDs were used as light sources. In the second experiment, all three chromatic lights were presented blinking on and off in one temporal sequence. In this case subjects were asked to report the perceived chromatic sequence of lights in the phantom array. We found that the phantom array was perceived as composed of a smaller number of dots or dashes compared to the stimulus projections on the retina and there was great intersubject variability in perception of the temporal sequence of chromatic lights.

This work was supported by the Research Council of Lithuania S-MIP-21-56"

Does blurry vision affect the glare illusion?

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The glare illusion is an optical illusion in which the central region is perceived to be brighter than its actual physical luminance due to its luminance gradient. Previous studies have used this illusion to investigate the mechanism of brightness perception, assuming that the participants have normal visual acuity. However, perception may be different because the luminance gradient of the glare illusion is not specific when the shape appears blurred, and it remains unclear how visual acuity affects brightness perception induced by the glare illusion. Therefore, we conducted an experiment that recorded pupillary responses which are known to reflect subjective brightness, to clarify the relationship between visual acuity and brightness perception by the glare illusion.

Participants observed five glare illusions varying in different sizes [visual angle: 5(deg)—15(deg)] with/without vision correction and compared their brightness to a control stimulus of the same size. The pupillary responses were recorded while stimulus presentation.

The results of the present study showed that there were no significant differences between the groups with and without vision correction on neither pupillary constriction nor brightness comparison. However, the pupillary diameter differed significantly based on the size of the glare illusion, and no significant difference was observed for stimuli in the control condition.

These results suggest that blurry vision does not affect the brightness perception and that the perception of brightness is enhanced as the size of the glare illusion increases. However, it is possible that degree of blur in this present study was not sufficient, therefore, further studies should take visual acuity and the degree of blur into account.

The illusory effects of makeup on the perceived eye slant are asymmetric

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Makeup utilizes various visual illusions to improve facial appearance. For example, eye makeup such as eyeliner, mascara,

and eyeshadow can alter the perceived slant of the eyes, making them appear slanted more upward or downward than they really are. These illusory effects have only been described as makeup artists' rule of thumb, and never been rigorously measured. Thus, we aimed to psychophysically measure the influence of makeup on the perceived eye slant. Standard stimuli were created by digitally applying makeup to an average face of young Japanese women. Comparison stimuli were created by physically rotating the eyes of the average face without makeup in steps of 1°. In each trial, one of the standard stimuli and one of the comparison stimuli were presented on a computer monitor, and observers judged which face appeared to have relatively more upward-slanting eyes than the other. The staircase method was used to calculate the perceived eye slant. The results of two experiments revealed two kinds of asymmetry. First, the magnitude of upward-slanting illusion was greater than that of downward-slanting illusion. Second, even with precisely the same makeup, the illusion that lessened the perceived eye slant (i.e., towards the average) was stronger than the illusion that increased it (i.e., away from the average). The theoretical and practical implications of these findings are discussed.

Revealing a hierarchy of prediction error signals using naturalistic video stimuli

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Violation of expectation (VoE) paradigms are widely used in psychology and neuroscience to investigate the workings of the perceptual system and our intuitive understanding of the world. However, most neuroimaging studies investigating surprise responses and predictive processing use VoE paradigms consisting of very simple and abstract paradigms that use unexpected stimuli or break newly learnt associations (e.g., odd-balls). In contrast, in this fMRI study we were interested in surprise responses to violation of seemingly impossible events using naturalistic stimuli. We constructed a set of video stimuli depicting three different violations of deeply held beliefs about the workings of the world – seemingly impossible object appearances, color changes and disappearances. Matching videos showing similar actions and movements as in the magic videos were used as control. Videos were presented with and without knowledge about the workings of the tricks. Comparing responses between magic and control videos revealed generic surprise responses in frontoparietal areas together with specific surprise responses in posterior visual areas. Moreover, we observed a decrease of activity predominantly in midline areas of the Default Mode Network (DMN) after explaining the tricks – supporting recent evidence that the DMN is involved in making sense of complex events unfolding in time. Surprisingly, event-specific prediction error signals in posterior visual areas were also modulated by prior knowledge, revealing that memory-based expectations about complex events shape representations already at the earliest cortical stages of visual processing. Together, our study provides evidence for a hierarchy of prediction error responses in the brain from frontoparietal to posterior areas and shows the presence of complex expectations in early visual areas.

Effect of room aspect ratio on verticality perception bias

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Perception of verticality is crucial for proper spatial orientation. Previous studies have shown that human perception of verticality is biased when daily scenes are tilted, and that this bias is represented by the sum of multiple periodic functions as a function of visual orientation. Specifically, the 180° component of the periodic functions is considered to be related to the horizontal cue, even though it is even produced in an indoor scene with no explicit horizon. In this study, we hypothesized that a large surface is easily recognized as a floor, providing an implicit cue to the horizon, and tested it by investigating the influence of the room aspect ratio on the 180° component. Using a head-mounted display, we presented an inside scene of an empty rectangular room (Experiment 1) or a rectangular aperture on the wall (Experiment 2), with three width-to-height aspect ratios of the room or aperture (1.2, 1.5, and 2). We presented the stimuli with a roll orientation ranging from -80° to 90°. Participants were asked to rotate a visual rod at the display center until it appeared vertical. We estimated the amplitude of two periodic functions (90° and 180° periodic) using the rod angle as an indicator of the influence of the visual orientation. In Experiment 1, the contribution of the room orientation increased for both 90° and 180° components of the rod adjustment bias as the room aspect ratio increased. In Experiment 2, only the 90° component increased with aperture aspect ratio, while the 180° component did not contribute to the adjustment bias. These findings suggest that an extended 3D surface provides a cue to the horizon in an indoor scene, leading to the contribution of the 180° component of the bias in verticality perception.

Supported by JSPS Grants-in-aid for Scientific Research (22K20315)

Revised model for explaining apparent rotational motion of shape distortion illusions

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When a circle and its blurred pattern are presented in alternation with a flash rate of about 2 Hz, the circular shape appears to transform into a polygon with slightly rounded corners and rotates slowly. If the perception of the circle is explained by the combination of outputs from a group of small line detectors arranged curvilinearly with a specific curvature, the perception of the straight parts in this distortion illusion can be explained by the adaptation of the line detectors, which causes the output of line detectors with lower curvature closer to a straight line to be relatively stronger. However, the process of forming the rounded corners cannot be explained. In the revised model, two constraints are introduced: 1) the output of line detectors with opposite curvature becomes relatively stronger after adaptation when they are adjacent to each other, and 2) the opposite outputs oscillate (alternate) in response to the flashing presentation. This enables the formation of the rounded corners and, at the same time, the phase (position of corners) of the polygon changes with each flash, resulting in the perception of apparent motion (rotation).

Acknowledgement: Supported by JSPS Grant-in-Aid for Scientific Research (C) 21K03145, (A) 21H04426, and RIEC Cooperative Research Project of Tohoku University.

Object Rigidity: Competition and cooperation between motion-energy and feature-tracking mechanisms and shape-based priors

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Why do moving objects appear rigid when projected retinal images are deformed non-rigidly? We used rotating rigid objects that can appear rigid or non-rigid to test whether shape features contribute to rigidity perception. When two circular rings were rigidly connected at an angle and rotated together at slow speeds, observers perceived them as rigidly connected. However, at moderate speeds, they reported that the rings non-rigidly wobbled and were not linked rigidly. Movies and window displays have used this illusion but there is no published explanation. These percepts contradict the conventional rigidity assumption. When gaps, paint or vertices were added, the rings appeared rigidly rotating even at moderate speeds. At high speeds, all configurations appeared non-rigid. Thus, salient features contribute to rigidity at slow and moderate speeds, but not at high speeds. Simulated responses of arrays of motion-energy cells showed that motion flow vectors are predominantly orthogonal to the contours of the rings, not parallel to the rotation direction. We trained a convolutional neural network (CNN) on 9000 motion flows to distinguish between motion flow patterns for wobbling and rotation. The trained CNN gave a high probability of wobbling for the motion-energy flows. However, the CNN gave high probabilities of rotation for motion flows generated by tracking features with arrays of MT pattern-motion cells and corner detectors. In addition, circular rings can appear to spin and roll despite the absence of any sensory evidence, and this illusion is prevented by vertices, gaps, and painted segments, showing the effects of rotational symmetry and shape. Combining CNN output that gives greater weight to motion energy at fast speeds and to feature tracking at slow speeds, with the shape-based priors for wobbling and rolling by Bayes' rule, explained rigid and nonrigid percepts across shapes and speeds (R2=0.95). The results demonstrate how cooperation and competition between different neuronal classes lead to specific states of visual perception and to transitions between the states.

Motion perception in illusory contexts

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Polarity-dependent orientation illusions, such as the café wall illusion and the work of Akiyoshi Kitaoka, clearly show how the contrast between background and inducing elements in static displays can strongly distort our perception of orientation (Todorović, 2021). In the current work, we begin to explore what happens when additional, dynamic elements are added to such displays. For example, what do we see when a moving object tracks along a contour that is physically horizontal, but appears tilted? Does the trajectory of the moving object also appear tilted? Or do we see its veridical, horizontal path? If there is conflict between dynamic and static elements in the display, does that eliminate or somehow modulate the static orientation illusion? Our preliminary findings, with six experienced observers, are quite clear. All observers report that the moving object tracks to the illusorily-tilted contour and appears to follow a non-veridical trajectory. To further explore this effect, we also asked observers to localize the position of the object after it disappeared using the classic representational momentum (RM) paradigm (Freyd & Finke, 1984). Consistent with the subjective reports of the motion trajectory, localization errors followed the direction of the static illusion, with memory for the same physically horizontal stopping point being shifted in the direction of illusory tilt. Additional studies with naïve participants are planned to further explore these effects and the roles that awareness, practice and bias may play in determining perceived motion in the context of illusions.

Concentric arcs illusion

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This study reports a new illusion. When multiple arcs with the same center position and central angle are arranged with different radius lengths, the ends of the arcs line up. However, it appears that they are not lined up in a row. When the arc angles are obtuse, the outer arc edge appears to be shifted toward the inner direction when compared to the inner arc edge. When the arc angles are acute, the outer arc edge appears to be shifted toward the outer direction when compared to the inner arc edge. We discuss the relationship between this illusion and existing ones (Jastrow illusion, Lipps illusion, Wada-Tanaka illusion, etc.).

Pitch-color associations under auditory illusion

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Individuals in the general population tend to map pitch height onto lightness (Marks, 1974; Ward et al., 2006; Wicker, 1968), as well as to specific hues (Hamilton-Fletcher et al., 2017), but not onto chromaticity (Ward et al., 2006). Critically, while Marks (1974) was not able to determine whether the pitch-lightness association was absolute or relative, Hamilton-Fletcher and colleagues (2017) reported that from 880Hz and above pitches are associated to yellow hues. We collected data from 6734 participants, who were asked to report the color that instinctively had the best fit to pitches ranging from C4 (261Hz) to B4 (493Hz). In the first block all participants heard the pitches in a random order once. This was followed by a second block where half of the participants heard the same pitches in an ascending order, and the other in descending order. Ascending and descending scales are supposed to create an auditory illusion by which the final pitches of the range are perceived as more extreme than they truly are. This illusion would allow us to evaluate to what degree lightness and color associations to pitch are modulated by bottom-up or top-down processes. We find that the ascending pitches were assigned higher lightness values than randomized ones, and oppositely the descending pitches were assigned lower lightness values. Comparatively, chromaticity values were not affected by the illusion. Regarding pitch association to the yellow color, we found that while it is assigned to an average of 419Hz when pitches are presented in a random order, it is associated to an average of 410Hz during ascending presentation and to an average of 440Hz during descending presentation. These results show that both pitch-lightness and pitch-color associations are subject to auditory illusion, supporting that pitch-color associations are relative rather than absolute.

The influence of visual illusions on time-to-contact perception

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Many situations in everyday life require the estimation of time-to-contact, that is the time it takes for an object to reach a specific position in space. Previous studies focused on object features or the type of information used by the observer to implement this process. Here we further investigated the characteristics of visual illusions that could affect time-to-contact estimation and try to disentangle between the cognitive "clocking" and "tracking" strategies explaining how observers deal with the occlusion period.

Two experiments were carried out using two well-known visual illusions: Muller-Lyer (experiment 1a and 1b) and Sander (experiment 2) illusions. A total of 19 participants were recruited for experiment 1a-1b and 62 participants for experiment 2. In experiments 1a and 2 participants were asked to perform a prediction-motion task, in which they were instructed to follow a moving dot until it disappeared and then to estimate its arrival at the end of the trajectory. To measure the actual perceived effect of the Muller Lyer illusion, in experiment 1b participants were asked to reproduce the length of stimuli used in experiment 1a using the adjustment method.

We found convergent results in favor of an influence of visual illusions on time-to-contact estimation. In experiment 1a, participants estimated longer time-to-contact when the Line Type had inward-pointing arrowheads. Moreover, they were prone to underestimate and consequently to shorten the stimulus length in the inward condition, while in the outward condition to overestimate and consequently lengthen its length (experiment 1b). Experiment 2 was a conceptual reproduction of experiment 1a and results showed significant longer time-to-contact estimation when the dot moved on the left diagonal compared to the right one.

Results confirmed the influence of visual illusions on time-to-contact estimation and because being equal using both illusions its underlying mechanisms seem to confirm the cognitive "tracking" strategy model.

Exploring the neurophysiological correlates of illusory self-motion (vection)

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Vection describes the sensation of self-motion in the absence of corresponding physical movement and is a common phenomenon when using Virtual Reality applications. Although vection is a well-studied phenomena, little is known about the underlying neurophysiological processes. Previous studies have identified a possible network of cortical areas (e.g., MT+, CSv, PIVC) that are involved during vection, and have used EEG measures to identify the early processing stages (e.g., N2, P3) linked to this experience. However, our knowledge of the neurophysiological differences between the states of vection and non-vection remains unclear. The main goal of this study was to address this issue. A total of 34 participants viewed a vection-inducing visual stimulus composed of black-and-white bars on an array of three monitors, moving in a horizontal direction with two different speeds (slow, fast). Participants pressed a button upon experiencing vection (i.e., onset time) and released it once vection disappeared (e.g., offset duration), and vection intensity was verbally recorded after each trial. Neurophysiological data were recorded using a 32-channel EEG system, and absolute spectral power and event-related spectral perturbations (ERSP) were calculated to compare spectral changes and variations in the time-frequency domain between vection and non-vection states. Preliminary results with a partial dataset (N=20) showed alpha power activity to vary as a function of vection state and stimulus speed. Specifically, a significant decrease in alpha activity was measured following vection onset compared to non-vection states. This decrease in alpha power only occurred for the slow-moving stimulus but not for the fast-moving stimulus, suggesting that the intensity of the stimulus may cause variation in neural responses to the same visual scene. The results of this study further enhance our understanding of the neurophysiological correlates associated with vection and can aid in the development of objective measures of vection in the future.

Seeing double… in time: single light pulses are seen as two separate flashes

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The visual experience elicited by short flashes does not always correspond to the physical stimulation, depending upon the inter-stimulus interval and the intensity of light. For example, two flashes may be seen as one if the ISI is relatively brief (<20 ms) due to insufficient temporal resolution of the visual system (two flash fusion), or may be misperceived as three flashes when the light intensity is high and inter-stimulus interval is around 80-100 ms (i.e., the triple-flash illusion).

Here, we report the results of an online experiment in which we instructed 80 participants to fixate on a central dot while they were presented with one or two lateralized suprathreshold flashes (17 ms) separated by a short inter-stimulus interval (ISI range 17-80 ms) and asked them to report with a keypress how many flashes they perceived.

Unsurprisingly, correct identification of two flashes followed a psychometric sigmoid function with respect to the ISI, meaning that longer ISI eased the discrimination of the stimuli. However, when only one flash was presented, most participants reported to see two flashes a significant number of times, ranging from 5% to 71% of trials across participants. Strikingly, the proportion of two flash responses in this 'one-flash' condition was significantly higher than when two flashes were presented at a short ISI of 17 ms ($p < .001$) and was weakly correlated with the psychometric threshold ($r(78) = -.22$, $p = .04$).

This temporal illusion has been previously reported using large but not small central stimuli, suggesting that it reflects the different latency of the cone and rod systems. Our results support this interpretation since lateralized stimuli are likely to activate both populations. Finally, the correlation between the magnitude of the illusion and the two-flashes discrimination threshold suggests that this factor should be considered and corrected when measuring the temporal resolution of perception.

Facial Expressions' Influence on Evaluation of Videoconference Recruitment Interviews

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Due to COVID-19's influence, opportunities to conduct interviews via videoconferencing have greatly increased. Previous research has shown that an interviewee's smile affects a recruitment interview's outcome, so this study examined facial expressions' effects in videoconference recruitment interviews. We simulated an interview situation to examine (1) the relationship between the interviewee's expressed positive/negative "valence," (2) facial expressions' intensity, duration, and variability (i.e., "engagement") and (3) the interviewer's ratings of the interviewee. To simulate an interview situation, 15 third-year

undergraduate students were asked to give one-minute speeches (video-recorded) of general self-promotion and their motivation for applying, using the online communication application Zoom. Afterward, companies' human resource managers (i.e., as interviewers) evaluated the recorded speeches for motivation for applying, self-promotion, and overall evaluation on a five-point scale. Valence and engagement were coded using Affedex, an emotion recognition AI based on movement of facial muscles, and then quantified using the average across frames. Next, valence and engagement were divided into groups based on their respective median values. High and low groups were compared according to the total mean of the three evaluation values: motivation for applying, self-promotion, and overall evaluation. Results showed marginally significant differences in both valence ($t(13) = 1.94$, $p = .075$. $r = .47$) and engagement ($t(13) = 2.04$, $p = .062$. $r = .49$). The greater the intensity of the interviewee's positive expressions, the better the interviewee's evaluation by the interviewer. These results not only reveal facial expressions' influence during interviews but also indicate the potential for developing training methods to help interviewees create effective facial expressions during videoconference interviews.

Human intracerebral recordings in the amygdala and fusiform gyrus during rapid periodic changes in facial expressions

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The ability to quickly decode emotional expressions from a person's face is critical for human social interactions. Despite a large amount of scientific research over the past 4 decades on the neural basis of facial expression recognition, the respective contribution of the human amygdala (AMG) and face-selective regions of the lateral fusiform gyrus (latFG) is heavily debated.

Here we report intracerebral electroencephalographic (iEEG) recordings in the AMG and latFG of both hemispheres from a large cohort of epileptic patients (N = 30). The paradigm is based on the presentation of rapid changes of a neutral facial expression to either a fearful, happy, or disgusted expression of the same face identity (Dzhelyova et al., 2017). Emotional faces appear every five faces in a train of neutral faces flickering at 6 Hz, leading to expression-selective responses at 1.2 Hz and associated harmonics (i.e., 2.4 Hz, etc.) identified objectively in the iEEG frequency spectrum. These expression changes of are presented at upright or inverted orientation in different stimulation sequences.

While the latFG show both expression-selective responses and general responses to faces (6 Hz and harmonics), the AMG show only expression-selective responses. However, both the proportion of significant contacts and their amplitude are much larger in the latFG as compared to the AMG for face expression-selective responses. Importantly, the amygdala responds almost exclusively to changes towards negative expressions (Fear and Disgust), whereas the latFG responds to changes towards all emotional faces. While stimulus inversion causes only a small reduction of expression-selective neural response specifically for disgust in the amygdala, neural activity is significantly reduced for all facial emotions in the latFG. Overall, these observations point to distinct and complementary roles of the amygdala and the lateral fusiform gyrus in the rapid detection of emotional facial expression changes in humans.

Incongruence in disguise between encoding and retrieval impairs face identification

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As mask-wearing becomes optional with more relaxed COVID-19 restrictions, people now encounter difficulties matching the identity of unoccluded faces to prior masked ones. Previously (Or et al., ECVP2022), we showed that masking faces during both study and memory test sessions (i.e., congruent disguises) did not reduce sensitivity (d'), but introduced a liberal response bias, compared to unoccluded faces. In contrast, wearing sunglasses, which covers the upper region of the face, significantly lowered sensitivity. Here, we investigated how incongruent disguises between study and test could affect face identification performance. In each condition, observers (N = 24 per experiment) 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) for judging whether each test face was studied before or novel. In Experiment 1, observers studied faces under three conditions; namely, (1) unoccluded faces, (2) faces with sunglasses, or (3) faces with face masks, and then they were always tested with unoccluded faces. In Experiment 2, observers always studied unoccluded faces but were tested with faces that were either (1) unoccluded, (2) with sunglasses, or (3) with face masks. Results from both experiments showed that sensitivities with incongruent disguises (ECVP2023) dropped 35% from those with congruent disguises (ECVP2022), for both sunglasses and face masks. All incongruent-disguise conditions showed significant declines in d' from studying and testing with unoccluded faces only, with consistently larger impairment in the sunglasses conditions than in the face mask conditions. The liberal bias tendency was also

observed among incongruent-disguise conditions. The results suggest that congruent disguises enhance face memory retrieval, and the upper face region containing the eyes is consistently more diagnostic than the lower face region during holistic face-identity processing.

Do facial expressions affect the memory of facial color in an achromatic color adjustment task?

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Adding color to a face modulates its expression. For example, an angry face can be perceived as more angry by coloring the face reddish, and facial expressions similarly affect perceived facial color. Additionally, humans memorize and recall facial color as more reddish and yellowish. These reports aim to clarify whether facial expression affects memory color in the relationship between perceived objects and their color. Do humans actually memorize the color of facial expressions, such as an angry face being more reddish than neutral? We conducted two color adjustment experiments to investigate whether memory color is affected by facial expressions. The stimuli consisted of four individuals' faces with three facial expressions (Anger, Neutral, and Fear) and one banana image as a control. A stimulus was presented, with its colors changeable along the axis of a line connecting the primary color of the stimulus and a physical neutral point on the a*-b* plane in the CIELAB color space. Participants adjusted the color of the stimulus on that axis till it became perceptually achromatic. In Experiment 1, the adjusted color of the banana stimulus significantly tended toward the opposite color from the physical neutral point, supporting the influence of memory color on perceived objects. Contrastingly, the face stimuli were adjusted almost till the physical neutral point. The amount of color shift from the physical neutral point positively correlated to response times, which might be caused by color adaptation. Hence, in Experiment 2, we shortened the stimuli presentation time using the staircase method to reduce the influence of color adaptation. As in Experiment 1, the banana stimulus indicated an effect on memory color, but the facial expression stimuli did not. Therefore, facial expressions would have a small effect on memory color. The sensitivity to discoloration and polychromatism of the face may explain these findings.

The neural basis of Face Identity Recognition in macaques with fMRI frequency-tagging

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The face has great significance for social interactions in primates and is the most diagnostic information for identifying specific individuals. While monkeys appear particularly proficient at recognizing gaze, head orientation and facial expressions, their ability to perform face identity recognition beyond image-based discrimination similarly to humans is questionable. Having recently validated a powerful frequency-tagging fMRI face localizer for non-human primate imaging, here we extend this approach to target the neural basis of monkeys' recognition of variable natural images of facial identities. FMRI recordings were performed in two macaques. Natural images of a single unfamiliar identity were presented within a rapid 6Hz stream in two conditions: (1) with the same image across low-level changes only, or (2) different image (background, head orientation, expression) changes additionally. Every 9s during a 243s run, 7 natural different unfamiliar identities were introduced in bursts. Either human or monkey faces were presented. Analyses were performed in the Fourier domain where individual face discrimination responses were objectively identified and quantified, at the peak of the identity change frequency (0.111Hz). Analyses focused on face-selective regions defined with our functional frequency-tagging localizer. In all these regions, image-based individual face discrimination responses were found in both monkeys for condition 1, whereas responses were negligible in condition 2, with little evidence of a significant inversion effect for human and monkey faces. In contrast, preliminary evidence from two human subjects tested in the same paradigm indicates robust individual discrimination effects across both conditions in their core face-selective ventral regions (OFA, FFA) and exhibits large inversion effects, restricted to conspecific faces. This extension of the frequency-tagging fMRI approach provides the first evidence of fMRI adaptation to different face identities in non-human primates. However, contrary to humans, this effect appears to be essentially restricted to image-based discrimination, with no significant advantage for conspecific faces.

Beauty in the Hijab – the influence of the religious garment and gaze direction on perceived facial attractiveness

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The Hijab is a headscarf that covers the head and the neck, worn by many Muslim women across the globe, primarily as a symbol

of modesty, privacy, and religious observance. Previous studies have demonstrated the Hijab reduced perceived facial attractiveness and may affect the perception of other personal attributes (e.g., intelligence and pleasantness) of women in both non-Muslim and Muslim populations. On the other hand, transient, non-verbal social cues such as eye gaze are known to influence the formation of first impressions. Direct gaze is often associated with social interest and engagement and may enhance facial attractiveness, as reported in some studies. However, the meaning of eye contact can vary across cultures. For instance, in some Muslim cultures, prolonged direct gaze or eye contact is considered a negative behaviour suggesting disrespect. Here we investigated whether hijab-wearing status and gaze direction interact on perceived facial attractiveness in a predominantly Muslim, but culturally diverse city - Dubai, UAE. In an attractiveness rating task (n = 147; 75 female), faces of 20 Muslim women were presented in 4 conditions: 1) Uncovered + direct gaze; 2) Uncovered + averted gaze; 3) Hijab-wearing + direct gaze; and 4) Hijab-wearing + averted gaze, for 2 seconds each. All faces with direct gaze, regardless of Hijab-wearing status, were rated as more attractive compared to those with averted gaze [$F(1, 146) = 60.34$, $p < 0.001$]. Surprisingly, uncovered faces were perceived to be less attractive than those wearing the Hijab [$F(1, 146) = 162.32$, $p < 0.001$]. There was no interaction between gaze direction and Hijab-wearing status ($p > 0.05$). A follow-up study using the Implicit Association Task is underway to further investigate whether the enhanced attractiveness judgements towards hijab-wearing faces reflects the positive connotations associated with the Hijab in the region. [This study is funded through the Internal Research Grant awarded to HAKY by Heriot-Watt University.]

Encoding of multiple images in unfamiliar face recognition

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Research has shown that providing an array of multiple, variable images of a face improves performance in matching unfamiliar faces. Multiple images provide information both about how a face varies in appearance across different viewing conditions, i.e., within-person variability information, as well as information about the stable and consistent features of the face. Which of this information is most useful and how it is encoded by viewers in an unfamiliar face matching task is still unknown. It is possible that viewers, when using information from the array, are abstracting some kind of average, stable representation of the array images which is used to match to the target face. Alternatively, array images may be encoded individually as pictorial codes to preserve variability information for use in recognition. In this study we tested these two types of encoding from an array in a sequential face matching task. Participants were presented with an array of four face images, followed by a short delay, then a target face and asked to make a same/different identity judgement. The target images were either of a matching or a mismatching identity to the array. When matching, the target was either (a) an average of the four images used in the array, (b) an average of a different four images of the same identity, (c) an image of the identity which was used in the array, or (d) a novel image of the same identity. Results provide insight into the nature of the face representations generated from multiple image arrays, and suggest that viewers utilise both pictorial codes as well as abstracted representations when using within-person variability information presented in a multiple image array of an unfamiliar face.

Breaking Through Ambiguity: Face-Likeness Reduces Breaking Time in Implicit Processing

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Previous studies have shown that humans can implicitly process faces faster than objects. Furthermore, upright faces are even perceived faster than inverted faces, even without consciousness. However, the mechanism of how our brain unconsciously processes ambiguous face images is still unclear. In our experiment, upright and inverted black-and-white binary face stimuli were presented in a 2AFC location discrimination task, combined with continuous flash suppression (CFS), a psychological technique that suppresses the perception of visual stimuli with rapidly changing masks. The time required for a stimulus to be perceptually recognized is called the breaking time (BT) and was recorded for each face stimulus. Additionally, upright and inverted grayscale face stimuli were also presented as control. Results showed that BT for inverted grayscale images was significantly longer than upright grayscale faces, while BT for upright and inverted binary faces did not reach statistical significance. Interestingly, a moderate correlation ($r = -0.52$, $p < 0.001$) between face likeness and BT was found after evaluating the face likeness for each binary face stimulus, with high-face-like binary faces exhibiting shorter BT and low-face-like stimuli resulting in more prolonged BT. Our results suggest that even an ambiguous object rated highly in face-likeness can reduce BT under implicit processing, indicating the possibility that facial parts such as the eyes and nose are subconsciously detected in ambiguous facial stimuli, enabling facial perception. [This work was supported by JST, the establishment of university fellowships towards the creation of science technology innovation, Grant Number JPMJFS2121. No conflict of interest.]

Do body gestures bias the perception of facial expressions?

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Other individuals' body gestures bias our classification of their facial expressions towards the emotion conveyed by their bodies. This well-replicated bias has been attributed to a change in the perception of people's faces, caused by their body gestures acting as contextual cues. Using a psychophysical method that largely eliminates the effects of non-perceptual processes on the judgments of facial expressions, we measured whether body gestures biased the perception of facial expressions that are easily discriminable (happiness and anger) or that are confusable (anger and disgust). In Experiment 1, eighty-four participants performed a discrimination task, where they viewed pairs of facial expressions picked from a continuum of expressions morphed between happiness and anger (through neutral), and indicated which of the two faces appeared closer to a neutral expression. The 540 trials were divided into three conditions; one where the faces appeared alone, one where they appeared with happy body gestures, and one where they appeared with angry body gestures. In each condition, we estimated the perceptual bias, reflecting the appearance of neutral expressions to the participant. We found that the mean perceptual biases did not differ between the three conditions, $F(2, 249) = 0.54$, $p = .585$, $\eta p2 = .004$. In Experiment 2, we performed the same experiment with another 84 participants using confusable expressions instead. When discriminating facial expressions along an anger-disgust continuum (morphed through neutral), perceptual biases did not differ between conditions that displayed faces only and those that displayed faces with an angry or disgusted body gesture, $F(2, 249) = 0.40$, $p = .668$, $\eta p2 = .003$. Our findings indicate that people's perception of facial expressions is not biased by body gestures, suggesting that previously reported biases in facial expression classification may have resulted from changes in higher-level decisional processes that occur beyond perception.

Concurrent selective neural indices for multiple high-level categories within a rapid image stream

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Face and object neuroimaging studies often aim to measure neural signals considered selective for a specific object category (e.g., via a subtraction of contrasting conditions). Recent work has established visual periodicity as a powerful and efficient tool that can be coupled with electrophysiology to capture the differential (i.e., selective) response to a given category of interest within a rapid image stream. We present a novel extension to this frequency-based approach that enables online dissociation of selective neural responses for multiple high-level categories appearing in the same rapid image stream. In two experiments, we exploit this technique to quantify how the selective neural responses for face and birds (Exp 1) and houses and birds (Exp 2) are influenced by the focus of category-based attention. The key finding is that the pattern of attentional enhancement and suppression for face-selective processing is unique compared to non-face object categories. Specifically, where attending to non-face objects serves to boost their selective neural signals, attentional enhancement of face-selective processing is comparatively very modest. Moreover, only the selective neural response for faces appears to be actively suppressed when observers attend towards another visual category. These results underscore the special status that human faces hold for the human visual system, and highlight the utility of frequency-tagging designs as a simple, yet powerful tool for indexing selective neural processing of multiple visual categories contained within the same visual sequence.

A Computational Study of Differential Importance of Facial Sub-Regions in Emotion Identification

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Faces are complex stimuli, consisting of a large number of visual features that pose a challenge to understanding the mechanisms underlying human face processing, such as emotion categorization. A number of empirical studies, e.g. via masking or eye-tracking, have suggested that different parts of the face may be differentially important for humans in the identification of different emotional states. However, few studies have systematically investigated the OBJECTIVE importance of different facial features in various facial categorization tasks. Here, we present a novel computational approach that allows the quantification of the "ideal" importance of each facial feature for the detection of facial emotions. We employ a latent feature space yielded by an Active Appearance Model, a feature representation we used successfully previously to characterize human face perception behavior, and found the optimal linear classification solution for different emotion identification tasks (happy, angry, fearful). We then present a visualization technique that allows the assessment of not only how much each pixel contributes to the identification of each facial emotion, but also how different parts of the face may contribute redundant information. Our results indicate that the detection of "happy" depends largely on information in the mouth region, but importantly, while there is also substantial useful information in the eye region, that information is highly correlated with that in the mouth region. On the other hand, for the identification of "fearful" or "angry", not only is most of the useful facial information in the eye and eyebrow region, but the useful information in the mouth region does not correlate with what is

available in the eye/eyebrow region. Thus, if a human observer must choose one location in the face to fixate for identifying different possible emotional expressions, our model predicts it is best to fixate the eye region – this has indeed been observed in human eye fixation studies. Moreover, if an observer for some reason prefers to fixate the mouth rather than eye region, then our model predicts that the person would be selectively impaired in "fearful" or "angry" identification but not "happy" identification - this has also been observed in individuals with autism spectrum disorder (ASD), who have been observed to relative prefer the mouth region over the eye region, and who are known to be selectively impaired in the identification of "fearful" and "angry" but not "happy." Our results demonstrate that human face processing is well adapted to the statistical properties of faces in the natural environment, and explain how and why certain behavioral impairments related to face processing may occur when covert attention is mis-allocated. More broadly, the computational techniques presented in this work can prove useful for the scientific study of other-race effects, which are known to be accompanied by race-dependent fixation behavior, as well as the development of novel diagnostic and treatment techniques in clinical populations with known deviations in fixation behavior and affect processing.

Concealed familiar face detection with EEG in rapid serial visual presentation

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Classical concealed information tests (CITs) are in some circumstances able to detect concealed information, but are also vulnerable to countermeasures that participants can use to shield concealed information from detection. Rapid serial visual presentation (RSVP) has proven effective against such countermeasures, and can thus substantially reduce type-II error. Research to date has relied on classic univariate analyses of EEG data. Here we investigated whether RSVP-based CIT with multivariate analysis (decoding) of the EEG is potentially more effective for detecting 'concealed knowledge' of familiar faces. 29 participants searched for a target face in an RSVP task while a familiar face (one of their parents' faces), or one of two control faces also appeared in the stream. Using neural-network decoding, we detected concealed information for each individual with an average hit rate of 61.8% and an average correct rejection rate of 72.7%, while accuracy was 49.4% (around chance level), when we decoded one control face from the other. In comparison, univariate analyses were only able to detect familiar face recognition in 19 participants. Our findings suggest that neural-network decoding makes RSVP-based CIT a more reliable method to detect concealed information.

Spatial and temporal complexity modulates pareidolia in dynamic fractal noise

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Seeing familiar objects or faces in random patterns (pareidolia) reflects the human visual system's propensity to perceive meaningful structure. We investigate what percepts emerge in dynamic synthetic noise patterns of varying complexity, defined by their 1/f spatiotemporal amplitude spectra. Participants (n = 68) were shown videos of greyscale, dynamic fractal noise patterns that varied in the fractal exponent of their spatial (0.25, 0.75, 1.25, 1.75, 2.25) and temporal (0.75, 1.25, 1.75, 2.25, 2.75) amplitude spectrum, where increases in the fractal exponent correspond to decreases in complexity. The stimuli were also symmetrical around the vertical mid-line or asymmetric. While viewing each video, participants were instructed to report any structure that they perceived in the stimulus. There was a greater number of responses for symmetrical stimuli, approximately 3 times as many as for the asymmetrical patterns. Approximately 60% of all responses were animacy-related, with participants' responses including human and animal faces and bodies as well as other beings (e.g., demons and dragons). Symmetry, temporal slope, and spatial slope had a significant effect on the number of animacy-related responses, with the number of responses peaking for symmetrical patterns with intermediate spatial and mid to high temporal slopes. Our results indicate that the spontaneous perception of structure in fractal noise patterns is facilitated by symmetry around the vertical mid-line as well as intermediate spatial and temporal complexity, and these patterns can elicit a wide range of percepts, from human faces to totem poles to mythical creatures.

Fixation patterns during and after face adaptation

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To recognize familiar faces fast and accurately despite changes (e.g., due to aging) face representations stored in memory adapt to new information. The adaptation process can be assessed experimentally by initially presenting strongly manipulated faces. In a subsequent test phase, participants are then

asked to choose the veridical face image out of manipulated and non-manipulated variants. Results typically show that participants tend to select an image slightly manipulated towards the previously seen adaptor as the veridical image. The experiment presented here used eye-tracking to explore whether fixation patterns on faces are sensitive to adaptation. Participants' fixation patterns on adapting and test faces were assessed in a variant of the typical adaptation paradigm. Results indicated that, as hypothesized, fixation patterns on test faces differed as a function of the nature of the adapting face. To the extent that fixations differ between familiar and unfamiliar faces, these findings suggest that adaptation is rooted in face familiarity: exposure to the adapting face shifts the corresponding mental representation of that face so that a veridical face subsequently appears less familiar. Eye-tracking may therefore be a sufficiently sensitive tool to explore adaptation processes in more detail in the future.

Is lateralization of face processing to the right hemisphere dependent on lateralization of word processing to the left hemisphere?

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Introduction:

It is debated whether lateralization of face processing to the right hemisphere is contingent on word processing being lateralized to the left hemisphere. According to the causal complementarity principle one should expect such a positive relationship because word and face processing compete for the same cerebral resources. We tested this prediction in a sample of 210 right-handed adults.

Methods:

The participants performed a divided visual field paradigm with delayed matching of faces, words, and cars. Given the limited stimulus exposure duration (150 ms), we used d' as the dependent measure. We performed Bayesian analyses of visual field (VF) differences and correlations between VF differences and stimulus type. The correlation analyses were based on both difference-scores [e.g., faces left VF – faces right VF] and ratios [e.g., (faces left VF – faces right VF) / (faces left VF + faces right VF)]. Analyses with cars were considered exploratory as we had no a priori expectations regarding this category.

Results:

There was extreme evidence for right lateralization for face processing [BF01 = .000, t = 5.15, p < .001], moderate evidence for left lateralization for processing of cars [BF01 = .015, t = -3.84, p < .001], and no/anecdotal evidence for left lateralization of word processing [BF01 = .637, t = -2.68, p < .01]. There was considerable evidence in favor of the H0 for the relationship between lateralization of face and word processing, and this regardless of whether the analyses were based on difference-scores [r = .02, 95% (-11, .15), BF01 = 17] or ratios [r = .003, 95% (-13, .14), BF01 = 18].

Conclusion:

We find the expected VF differences for faces and words but no support for the proposition that the degree of right lateralization for face processing depends on the degree of left lateralization for word processing.

Facial colors modulate the recognition of anger in multiple faces

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We can extract an average emotional expression when seeing a group of faces. This study investigated the effects of facial colors on recognizing anger in multiple faces. An expression continuum was created using morphing software between neutral and angry expressions for a male and female face. The emotional intensity was defined by morph percentages ranging from 0% (neutral) to 100% (angry). Red and pale facial colors were determined based on the simulation of natural skin color variations resulting from changes in facial blood flow (hemoglobin concentration). In each experimental trial, four face images were presented for 1.0 seconds, each face with an emotional intensity of -18, -9, +9, and +18 morph percentages relative to a mean emotional intensity that was varied in five levels around 50 morph percentages. Observers were asked to indicate whether or not the average expression of the set of faces was angry. The frequencies of recognizing anger were measured by presenting each set of faces 20 times. The congruency between relative emotional intensity and facial color was manipulated in different facial color conditions. Results showed that facial colors significantly affected the recognition of average expressions when associated with angry faces. Specifically, making the angry faces (+9 and +18 morph percentages) red facilitated the anger recognition while making them pale hindered it. No significant effects were found for other associations between the relative emotional intensity and facial color. When all faces in the set had the same standard color, the threshold of recognizing anger was almost the same as that obtained with a single face, suggesting angry faces were not heavily weighted in summarizing facial expressions. The findings suggest that facial colors modulated the perceived emotional intensities of individual angry faces, which were then averaged with those of other faces in the set.

Effects of emotional Intelligence and emotional creativity on the perception of composite faces

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The relationship between emotional intelligence (EI) and emotional creativity (EC) is ambiguous: results of experiments show that individuals with high EI may have low EC scores and vice versa. In addition, the question of the top-down influence of these constructs on lower-level perception processes is poorly understood. Faces from the P. Ekman database with basic expressions were selected as stimuli. Composite faces were additionally created for the experiment, in which the upper part of one expression was combined with the lower part of the same face, but with a different expression. A total of 38 stimuli were selected (2 actors X 6 basic expressions + 13 composite expressions). In the first part of the experiment, the subjects (N=57) were presented with one of the faces for 1 second. After that, a list of 32 emotions from R. Plutchik's theory appeared on the screen. The subjects were instructed to select the emotion(s) that most accurately describes that person on the screen. The subjects were told that they could choose any number of emotions. In the second part of the experiment, the same stimuli were presented, but the task was different. The instructions were as follows: «Think about the situations in which a person can have such a face and type your answer using the keyboard. You are not limited in the number of situations». Then the participants took an emotional intelligence test (TEI, Sergienko et al., 2019) and filled out an emotional creativity questionnaire developed by J. Averill (ECI, Valueva, Ushakov, 2010). ECI scores were not related to the number of created situations, their creativity or the number of words used to describe them. The average number of invented situations is occurred to be more associated with EI. The average number of invented situations was significantly positively associated with Tree 3 "Understanding emotions" (r (57) =.346, p=.008), Spearman's test.

Funded by RSF, project №19-18-00474-П

Refugee children's perception of facial emotional expression

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Atypical emotion perception, such as heightened attention to threat and overidentification of negative expressions, can impact children's psychosocial functioning and has been linked to experiences of early stress. Emerging research suggests similar atypicalities are also present amongst children who suffered war and displacement related adversity, but the specific visual biases and their mechanisms in the refugee context are still largely unknown. Here, using three different perceptual tasks, we investigated how war trauma exposure and refugee status affect facial emotion recognition in school-aged children. We collected data from Syrian refugee (n=130, Mage=9.3 years, 63 girls) and Jordanian non-refugee children (n=148, Mage=9.4 years, 66 girls) living in Jordan. Children differed in trauma exposure, but not on any of the mental health measures. Experiment 1 used a standard emotion recognition bias paradigm with different identity facial expressions morphed between happy and sad. We found that both refugee and non-refugee children perceived ambiguous expressions as sad, with no differences in bias patterns between the groups (difference in % morphing=0.4, 95%CI [-7.4, 8.5] In Experiment 2, we adapted a novel perceptual scaling task which bypasses semantic labelling, using morphed stimuli from Experiment 1, and again found no differences between the two group's discrimination of facial expressions (OR=0.68, 95%CI [0.36, 1.25], p=.22). Finally, in Experiment 3, we recorded children's eye movements as they categorised various (unmorphed) facial expressions, and again found no differences between the groups in either their identification accuracies or scanning strategies (dwell, first fixation, gaze duration; all Bayes Factors < 0.02). Children's emotion recognition biases were also not linked to their trauma levels or mental health outcomes across the three tasks. Our findings indicate that refugee status and caregiver-reported exposure to war-related trauma during early development does not impact emotion perception in the same way as other forms of adversity.

Coarse-to-Fine Integration in Human Face Identity Recognition

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Natural images contain multiple spatial frequencies (SFs), encoded by the visual system when processing complex visual input. The coarse cues conveyed by stimulus low SF (LSF) are processed rapidly and thought to guide the slower processing of the fine-grained high SF (HSF). In a recent neuroimaging study, we disrupted such coarse-to-fine processing by backward masking LSF or HSF of otherwise full-spectrum face stimuli over time. We found masking LSFs to be initially very disruptive, decreasing in influence over time, while the opposite trend was seen for HSF masking. This pattern of activity is in line with the coarse-to-fine theories and was observed in V1, dorsal, and frontal brain regions. In the fusiform face area (FFA), response increased with stimulus onset asynchrony (SOA) more steeply when masking HSF than LSF. The present study addresses

whether such disruption of coarse-to-fine processing has any impact on behavior. To this end, we used SF backward masking in a behavioral face identity recognition task. We presented full-spectrum face images of familiar celebrities and used SF backward masking to disrupt the processing of LSF (<1.75cpd) or HSF (>1.75cpd) at gradually increasing SOAs (50-150ms). We manipulated the signal-to-noise ratio (SNR) of the target face using a staircase method to assess the threshold SNR required to achieve 75% accuracy in all conditions. Linear mixed modeling revealed that for both LSF and HSF masking, the SNR threshold decreases significantly with SOA. Most interestingly, the slope of such decrease was steeper when masking HSF than LSF, mirroring the processing profile in FFA. Consistent with the coarse-to-fine hypothesis, we find that LSF processing is fast and transient while HSF processing is slower, more sustained, and relies more on recurrent processes. These findings highlight the importance of coarse-to-fine processing strategy, demonstrating its impact on performance in complex face identity recognition tasks.

Emotional faces break free faster than neutral faces and meaningless images of isoluminant visual stimuli

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Continuous flash suppression (CFS) has been widely used to investigate the effects of semantic or emotional processing on visual perception. Emotional facial expressions are generally detected faster than the neutral ones, suggesting a top-down modulation of visual processes driven by the emotional content of the stimuli. Here, we measured accuracy and reaction times for different emotional facial expressions (happy, fearful, neutral) and their phase-scrambled versions using breaking CFS (b-CFS). Stimuli were matched in terms of luminance. To the right eye, we presented a stream of Mondrian patterns, which temporarily suppressed the visual stimuli presented to the left eye. During the task, we also collected physiological measures, including heart rate, skin conductance, pupil size, and facial muscle activity which will be considered in future data analyses.

Behavioural findings showed that participants became aware of the face images faster than their scrambled versions. Furthermore, happy faces were detected faster and more accurately than fearful or neutral faces, a finding in line with previous studies on emotional face recognition but in contrast with previous reports using a b-CFS paradigm in which fearful faces yielded shorter suppression durations. Critically, such an advantage for happy faces was not observed for the scrambled images, suggesting that low-level features cannot explain this result.

Taken together, our findings demonstrate that positive emotional expressions break through suppression more easily when stimuli are equated in luminance. Analysis of the physiological responses will reveal if implicit processing of emotional content precedes or follows its conscious appraisal.

Spectral and color variations found in hyperspectral images of the skin of human faces.

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Point-contact methods for measuring the reflectance of the skin measure the average reflectance across small areas, without recording spatial context or spatial spectral variations. The purpose of this work was to assess the variability of the reflectance and color found in small areas of the skin of human faces, compared to the local area average.

Spectral data of skin of four human faces was acquired using a Hyperspectral Imaging System (HIS). Each image pixel subtended about 0.7′ of visual angle containing reflectance data from 400 to 720 in 10 nm steps. Nine specific facial positions were selected from each hyperspectral image, comprising about 8000 pixels each (about 300 mm2). Reflectance was converted into CIELAB chromaticity coordinates assuming the CIED65 illuminant and the CIE 2006 10° cone-fundamental-based colorimetric observer. For each area, reflectance and color variability were estimated by computing the Root-Mean-Square-Error (RMSE) and the color difference (CIEΔE) of each pixel against the local data averaged across the area, respectively. Data averaged across the local area was assumed to be equivalent to the unique measurement to compare against. RMSE, CIEΔE(L*,a*,b*) and CIEΔE(a*,b*) values were then averaged across one facial position, 9 facial positions from one participant, and 9 facial positions from 4 participants.

It was found that the average RMSE, CIEΔE(L*,a*,b*), and CIEΔE(a*,b*) were, respectively: 0.03±0.02, 2.8±1.4 and 1.9±1.1 for one facial position; 0.03±0.03, 3.0±2.2 and 1.8±1.0 considering 9 facial positions; and 0.04±0.04, 4.3±3.7 and 2.2±1.5 for 9 facial positions and 4 faces.

These results seem to suggest that taking only one measurement of the reflectance of an area of the facial skin may leave behind important local reflectance and color variations, visible to the naked eye. Combining spatial and reflectance information as obtained with the HIS seems to provide localized information that other methodologies fail to consider.

Age-related perceptual changes for gaze direction and portrait rotation caused by the Mona Lisa effect.

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The gaze and face orientation of a person depicted in a portrait painting appears to follow the observer even when they move around. This is called the Mona Lisa effect. Morita et al. (2020) suggest that this effect occurs from conflict between depth cues related to judging the gaze and face orientation of the depicted person. In this study, we examined whether infants perceive the Mona Lisa effect and compared their performance with those of adults. We evaluated the Mona Lisa effect by following indices: looking time to the eyes of the depicted person, preference for faces that did not cause the Mona Lisa effect, and pupil diameters.

In the experiment, we presented infants (five- and seven-month-olds) and adults 2D portraits of four persons individually and measured the looking time to the eye areas. The persons in the portrait had either directed or averted their gaze toward observers and the rotation angles of the portraits were designated at -20 to + 20 degrees. We then presented two depicted persons in left and right positions on the display and measured the preferential looking time for each person. The looking time and pupil diameters were measured by an eye tracker. The results showed that infants looked into the eyes of depicted persons independently of gaze direction and portrait rotation. The older infants and adults showed more preference for the person with a directed gaze than that with an averted gaze regardless of portrait rotation. Moreover, pupil diameters tended to be larger when observers of all ages looked at the directed gaze portraits than when looking at the averted gaze portraits. These results suggest that seven-month-old infants could perceive the Mona Lisa effect and a preference for an averted face and pupil dilation can be efficient indices of the Mona Lisa effect.

Cues accounting for the horizontal tuning of human face identity recognition

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Human identity recognition recruits specialized visual mechanisms that preferentially rely on the horizontal content of the face stimulus. Here I will present works addressing the nature of the information contained in the horizontal range of the face stimulus. A parallel project shows that the identity cues conveyed by the horizontal range are the most stable across viewpoints and predict viewpoint-tolerant identity recognition in humans. The present project investigates how inversion and negation affect the horizontal tuning of human face recognition, as these manipulations are thought to prevent access to distinct sources of information: feature configuration and surface properties, respectively. Participants performed a face identity recognition task using famous actors face-images. Orientation-filtered images (from 0° to 150° in steps of 30°) were presented upright with a positive contrast, inverted, or negated. We modeled the inversion and negation effects across orientations using a Bayesian Gaussian mixed model. Overall, inversion impaired sensitivity more strongly than negation, but the orientation profiles of the inversion and negation effects were correlated and described a similar gaussian, peaking in the horizontal range. This indicates that inversion and negation similarly disrupt access to the oriented content of the human face. The horizontal range of face information being the most vulnerable to these image manipulations, which –though radically different at the pixel level– are especially harmful to face perception, indicates that this range provides access to the optimal configural and surface cues for the specialized processing of face identity.

Altogether, our findings suggest that the horizontal range is essential for face identification not only because it conveys feature configuration, but also the surface cues that are crucial for the tolerant representation of human face identity.

Contributions of low-level mechanisms to (non)face-specialized contextual mechanisms

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Face contextual modulations have been attributed to specialized mechanisms implemented at high-level regions of the visual processing hierarchy. Their possible connection to V1-based mechanisms has been little studied despite striking functional similarities, notably the dependence of low- and high-level contextual mechanisms on local input strength. Here I'll discuss how we investigated the amount of variance in face contextual modulations that is explained by V1-based contextual mechanisms by exploiting this shared dependence in a series of behavioral experiments and neural measurements. The same group of participants performed a contrast-detection and an eye matching task in upright and inverted faces that tested their ability to process local features independent of context at low- and high-levels of visual processing. The magnitude of contextual modulation for upright faces and contrast-detection did not correlate despite their shared dependence to local input strength. However, we found a correlation in contextual modulation magnitudes between inverted faces and contrast-detection. Following up, motivated by the past findings showing that V1 size can predict low- to mid-level contextual illusions, we measured the functionally defined size of V1 in a subset of the same sample. Functionally defined V1 size predicted

the behavioral contextual modulations during contrast detection task and eye matching in inverted, but not upright faces. Our results suggest that non-face-specialized high-level contextual mechanisms (inverted faces) work in connection to V1-based mechanisms. The engagement of face-specialized mechanisms for the processing of upright faces either obscures this connection or renders it inconsequential. The combined study of (non-)face-specialized and V1-based contextual modulations sheds new light on the functional relationship between different levels of the visual processing hierarchy, and thus on its functional organization.

The psychophysics of facial age perception

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Humans use faces as an immediate source of visual information about a person's age. Yet, data from our lab and others point to several biases and inaccuracies in age estimation from faces. For example, smiling faces are typically perceived as older than faces with a neutral expression. In addition, the accuracy of age estimation decreases for faces of older compared to younger adults and for expressive, compared to neutral faces. Other biases and inaccuracies in age estimation have been identified for faces of different ages and for male compared to female faces. Here, we provide careful examination of the psychophysics of human age perception. We also describe a comprehensive comparison between age estimation by human observers and current AI technology, showing that AI suffers from the same biases and inaccuracies as humans, but to a much larger extent. Finally, we discuss the strengths and weaknesses of current measures of age estimation and integrate these ideas to investigate whether age perception is achieved in a holistic manner across faces of different ages.

A hooligan game for isotropic looking gentlemen – Anisotropy values of facial photographs are related to success in Rugby World Cups

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Habitually, people assume that the facial appearance hints at a person's character traits (Likeability, Trustworthiness, Competence, Extraversion, Threat, Dominance). Furthermore, in images of faces, perceived character traits are associated with global image properties like Anisotropy. Anisotropy is a measure for the distribution of orientation of gradients in a particular image. Higher values in Anisotropy represent more angular (facial) features. When analyzing artificially created facial images (Todorov database), Anisotropy correlates negatively with perceived Trustworthiness and positively with perceived Dominance. This means that angular faces are evaluated as less trustworthy, but more dominant. In the present study, standardized portrait photos of players from Rugby World Cups 2015 (n = 176) and 2019 (n = 615) were analyzed for Anisotropy. Then, the means for the statistics for each squad were calculated and it was analyzed whether these can be associated with the Team Rating (originating from the team's win-loss record with lower ratings representing better teams) in the respective tournament. For both tournaments, Anisotropy correlated positively with Team Rating. Therefore, teams consisting of players with less anisotropic facial photographs were more likely to succeed. As an important note, Anisotropy is not linked to the ethnicity of the respective players. Combining the two findings, less anisotropic face images can be associated with perceived Trustworthiness and wins in Rugby competition, while more anisotropic face images are linked to perceived Dominance and losses in Rugby competition. In sum, the results provide evidence that global image properties (in this case Anisotropy) of facial photographs can be associated with success in competitive sports. Possibly, future studies will investigate whether there is a direct connection between perceived Trustworthiness and success in Rugby competition.

Perception of symmetry of familiar and unfamiliar faces

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The perception of facial symmetry is generally considered in comparison with the assessment of facial attractiveness, while far fewer studies have focused on symmetry perception mechanisms. For instance, the perception of symmetry has been shown to be affected by inversion (Rhodes et al., 2005; Luniakova, Kurenkova, 2023). This study explores whether familiarity of a face influences how symmetrical it looks.

The sample included 30 people (25 classmates and 5 teachers). All participants have known each other for over 5 years and meet regularly. Black-and-white neutrally expressed full face photographs were used as stimuli (20 images of participants' faces and 20 images of unfamiliar faces). Overall facial asymmetry (Penton-Voak et al., 2001) was calculated for each face image, and the distribution of facial asymmetry index was similar in groups of «familiar» and «unfamiliar» faces. Prior to enrolment in the study, all participants had given written consent.

The photographs of original faces and their horizontally mirrored versions, totalling 160, were presented to the participants one by one for 2000 ms each. The participants had to rate the asymmetry of the presented faces on a ten-point scale.

Self-face photo ratings were excluded from the analysis. Wilcoxon signed rank test revealed a significant difference in the ratings of the original and the mirror images of familiar faces (n=588, Z=3.78, p<0.001), while there was no difference between the ratings of the original and the mirror images of unfamiliar faces (n=600, Z=0.99, p=0.318).

The results showed that familiarity of a face influences perception of its symmetry. Mirror images of familiar faces are perceived as more asymmetrical than the original faces, although the objective parameters of facial symmetry remain unchanged. No such trend was found for unfamiliar faces. Supported by Russian Science Foundation Grant № 19-18-00474-П.

Face experience may modulate preference for mother's faces in infants raised during the COVID-19 pandemic in Japan

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Infants develop a significant ability to process mothers' faces in a usual social environment. Newborns prefer and recognize their mother's faces (e.g., Pascalis et al., 1995), and infants aged around 7 months process their mother's face in more adult-like manners (e.g., Kobayashi et al., 2020).

COVID-19, however, has modified numerous aspects of infants' social environments. Uncommon in the world, people in Japan have been wearing face masks for about 3 years since the beginning of the COVID-19 pandemic. Therefore, most infants, who were born after the COVID-19 pandemic, can only see the unmasked faces of very limited people, e.g., their immediate family members. These reductions and/or bias of face experience might affect the development of processing of the mother's face. This study examined the effect of wearing face masks on a visual preference for their mothers' faces.

Infants aged 5 to 8 months who were born in three different sites in Japan (Aichi, Niigata, and Tokyo) during the COVID-19 pandemic were presented to their mother's face and an unfamiliar female face simultaneously. We calculated infants' preference for their mother's face under two conditions: No-mask and Mask conditions. We also collected self-reported data from the parents who responded to our survey about infants' experiences with faces. Group analysis showed that infants in Aichi and Niigata significantly preferred their mother's face in both conditions. In contrast, infants in Tokyo significantly preferred their mother's face in the Mask condition, but not in the No-mask condition. Importantly, the preliminary analysis of the relationship between individual preference and self-reported data revealed a tendency that infants who did not prefer the mother's face in the No-mask condition had less exposure to no-mask faces. These results imply that experience with no-mask faces in daily life may modulate the development of processing of the mother's face.

Reading masked faces: updated narratives

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Facemasks became a popular topic due to the COVID-19 pandemic. This theme remains in the focus of research attention, because masks as well as other forms of face covering not only reduce an overall amount of face information available but introduce psychological biases and prejudices affecting social perception at large. The review 'Reading covered faces' [Pavlova and Sokolov, 2022; Cerebral Cortex] offered the first comprehensive analysis of the topic. Here I consider trends and directions in societally relevant investigation of face covering impact on social cognition and interaction. In a nutshell, the ensuing work nicely dovetails with and enriches the outcome of initial studies. Yet, several issues remain rather controversial or even paradoxical. First of all, effects of face mask wearing on first personal impressions such as approachability, trustworthiness and even attractiveness appear perplexing. Second, there is still a lack of rigorous experimental developmental (including healthy aging), cross-cultural and brain imaging work, in particular, in individuals with mental diseases. One of a reason for this is that 'face-to-face' experimenting under the COVID-19 pandemic conditions was obviously limited, and, therefore, most research remained online. This may create a sampling bias (e.g., the studies samples are heavily dominated by females) precluding a proper generalization of findings. The outcome of our 'face-to-face' study on emotion recognition in masked faces in patients with schizophrenia and major depressive disorder will be presented. Other limitations currently remain as well, namely: (i) displayed (by performers asked to demonstrate) instead of natural 'truly felt' emotions; and (ii) basic emotions instead of complex mental states in daily life. Finally, clarification of how masks affect face reading in the real world, where we deal with dynamic faces and have entrée to additional valuable social signals such as body language is in the focus of my analysis.

Face pareidolia: impact of gender and cultural background

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Face tuning to non-face images such as shadows or grilled toasts is termed face pareidolia. Face-pareidolia images represent a valuable tool for investigating social cognition in mental disorders. Here we examined whether, and if so, how, (i) face pareidolia is affected by subtle cultural differences; (ii) and whether this impact is modulated by gender. With this purpose in mind, females and males from Northern Italy were administered a set of Face-n-Thing images, photographs of objects such as houses or waves to a varying degree resembling a face. Participants were presented with canonical upright orientation and display inversion that heavily affects face pareidolia. In a two-alternative forced-choice paradigm, observers had to indicate whether an image resembled a face. The outcome was compared with the findings obtained in the Southwest of Germany. With upright orientation, neither cultural background nor gender affected face pareidolia. As expected, display inversion generally mired face pareidolia. Yet, while inverted displays led to a drastic reduction of face impression in German males as compared to females, no gender differences occurred in Italians. In a nutshell, subtle cultural differences do not generally sculpt face pareidolia, but instead affect face impression in gender-specific ways under unusual viewing conditions. Clarification of the origins of these effects requires tailored psychophysical and brain imaging work. Implications for transcultural psychiatry, in particular, for schizophrenia research, are highlighted and discussed.

Predictive perception: serial dependence, optimality and neural oscillations

David Burr[1]

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Richard Gregory proposed that perception is not a passive process that convertes external sensory input into perceptual experience, but one that makes active predictions (or "hypotheses") based in part on past experience, and verifies these predictions against incoming data. Serial Dependence is a clear example of how recent stimulus history strongly influences perceptual judgments, reflecting the action of predictive mechanisms. We model these predictive effects with an ideal observer model based on an adaptable Kálmán filter. For a range of attributes (numerosity, orientation, facial gender and expression), the model predicts well the magnitude of serial dependence, qualitatively and quantitatively. Experiments in both vision and audition suggest that the dependence on perceptual history may be mediated via alpha-frequency neural oscillations, akin to a "perceptual echo". Finally, we recently extended this idea and measured and modelled the well-known effect of visual crowding. The results suggest that crowding is best understood not as a processing bottleneck, but as a consequence of efficient exploitation of the spatial redundancies of the natural world, just as serial dependence exploits temporal redundancies. Taken together, the work supports Gregory's intuition that perception depends strongly on internal models of the world, constantly updated from sensory experience.

Polaris & the Plough illusion

Kentaro Usui[1], Akiyoshi Kitaoka[1]

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The North Star is the star that always shines in the direction of true north and tells us the exact direction of north. The best known method of finding the North Star is to use the Plough in the constellation Ursa Major as a landmark. The Plough is a group of seven bright stars in the shape of a large ladle. Identify the two stars at the end of the ladle: Alpha and Beta. Extend the distance between these two stars by a factor of 5 in the direction of the ladle's open mouth, and you will find Polaris shining there. However, depending on the angle of the constellation, Polaris may appear to be displaced from its extension. We discuss this new misalignment illusion.

Flicker-induced Gradation

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[1]Ritsumeikan University, Japan

In our presentation, we will demonstrate a novel illusion in which a flicker between alternating colors (e.g., black and white) elicits a vivid perception of gradation, even though the pattern itself doesn't contain any color or luminance gradation. This effect was discovered during our observations of Benham's top. We will showcase this phenomenon using physical instruments, specifically a Benham's top with patterns that induce this illusion, and through a video presentation.

You can find links to the demonstrations here: https://editor.p5js.org/kohske/full/vpZUe7LrE. On the left side, you will see white lines on a black background, and on the right side, black lines on a white background. In the middle, there appears to be a black-to-white gradation, but this is an illusion. In reality, the middle section is just an alternation of black and white squares. If you cover the left and right sides with your hands, the black-to-white gradation will disappear (though an unstable gradation pattern may appear).

Here is another version of the demonstration: https://editor.p5js.org/kohske/full/WpWWYL2yD.

In this case, you will also notice an illusory black-to-white gradation in the middle area.

The following demonstration contains multiple instances of flicker-induced illusory gradation: https://editor.p5js.org/kohske/full/4_ytIQ6MP.

Anti-Sensory Visual Illusion of Spinning Motion

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We present an illusion of spinning and show that it contradicts the sensory evidence provided by the stimulus. We also demonstrate that the spinning illusion is based on prior expectations influenced by the order of rotational symmetry, that adaptation to real spinning attenuates the illusion, and that natural sounds can bias it.

Video1: When a circular ring is translated on top of a line, observers report it as rolling and rotating/spinning. Real spinning of the ring would generate local velocities that are tangential to the contour, but motion energy outputs show signals orthogonal to the contour, and feature tracking shows signals along the translation direction. Therefore, the illusion of spinning contradicts neural evidence.

Video2: The spinning illusion is also seen when a circular ring is revolved around a central fixation point. The illusion is weakened and then abolished as the order of rotational symmetry is reduced progressively from infinity to four by introducing evenly spaced gaps in the contour or using regular polygons with corners. The transition generally occurs at rotational symmetry of order 8. This order also holds when paint is used to convert a hexakaidecagon to order 8.

Video3: After exposure to 20 seconds of adaptation to a physically spinning ring with four gaps, a revolving circular ring is seen as only revolving (not spinning) for about 10 seconds but then switches back to the illusory spinning. This suggests that the spinning illusion is due to activation of sensory units that signal motion tangential to the contour, and that the activation of these units by prior expectations overcomes stimulus-evoked neural signals.

Video4: When the sound of slipping on a floor is played simultaneously with the translating circular ring, the slipping sound biases the percept towards translation. The sound of a ball rolling biases the percept towards spinning.

Smooth and gradual extension of stereoscopic spatiality recorded by two drones

Martin Dokoupil[1]

[1]West Bohemia University, Czech Republic

My contribution to The Illusion and Demo Night, is part of my dissertation, in which I am researching The adaptability of human perception to expanded spatiality in correlation with the perception of time. This slowly emerging effect, the gradual illusion of a deeper space, is an absolutely breathtaking experience.

I am a visual artist and the study of stereoscopy and the psychology of perception has been with me nearly all my life. Finally my dream came true and I was able to realize the footage I have been dreaming of for years.

Following a virtual simulation of eye distance changes in motion and parallax variables in 3D software, I am capturing selected situations in a real world situation using two identical drones.

I explore the possibilities of how to "play" with the limits of human perception. The augmented binocular perception of the perceived space is not only a very powerful experience for the spectator, but also an opportunity to peer into the universe of multidimensional perception and into the secrets of perception of time (human perception).

Each stereoscopic video is approximately 30 seconds long and in the ideal situation the viewer can move on the timeline independently.

The online Rocking Line Illusion

Ian M. Thornton[1], Dejan Todorovic[2]

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We will introduce a new visual illusion that is easy to experience in a demo setting and provide an introduction to a freely available online version, where the effect can be experienced and relevant parameters manipulated. The “rocking line illusion” (RLI) occurs when a moving object passes through contrast boundaries formed by static background elements. Specifically, as a target object smoothly translates along the midline of a background checkerboard, two very different percepts occur, depending on spatial scale/viewing distance. With relatively large elements (all rectangles ≃ 2° visual angle), a veridical impression of horizontal motion occurs. However, when the display is scaled down in size – or the observer simply moves backwards – a compelling impression that the moving object rocks around its own centre begins to dominate. We will demonstrate the basic effect, discuss the importance of scale, and show how

the online version can be accessed and used to create novel variants by manipulating the available parameters.

You Through Me

Kalliopi Ioumpa[1]

[1]Netherlands Institute for Neuroscience, Netherlands

"You Through Me" is an interactive project that employs Virtual Reality technology to facilitate a body swap illusion, enabling participants to see the world from each other's perspectives.

The creation of the work was driven as an invitation to considered our personal perspectives and biases, re-relate with ourselves, each other and the world. The project emphasizes the importance of empathy, embodied knowledge, and experiential understanding. Through this immersive experience, participants also gain a heightened awareness that they are perceiving the world through someone else's viewpoint, without having agency over their own experiences. This realization prompts a contemplation of how we often delegate responsibility for our perceptions in various ways without fully recognizing it. Simultaneously, the exchange between participants cultivates a sense of mutuality and cooperation, as one participant is invited to consider the other's perspective and make decisions about sharing and responding to what has been shared.

For its design, I have used software that are freely available to make the set up easily reproducible by anyone interested in doing so. Instructions for reproducing it will be handed out. In this way the work becomes accessible to the wider community, inviting individuals to reconsider their relationship with technology and explore alternative creative applications.

I have already presented this project at art exhibitions and festivals where artists, scientists and the general public had the opportunity to experience it.

Paradox Box Story (by Paradox Museum)

Paradox Museum[1]

[1]Paradox Museum, Cyprus

Some say, 'mirrors are my best friend because when I cry, it never laughs.' Symbolically, mirrors reflect the truth. But! The Paradox Box exhibit challenges the observer to see that even the truth can be mirrored differently as a result of reflection and position.

This exhibit defies the laws of physics and provides a paradoxical experience where two different objects are seen inside the same absolute space. It is all made possible by mirrors that have been positioned diagonally with an infusion of geometry too. What's happening is that the geometric shapes are halves of a pyramid and cube; they are reflected by the mirrors as a whole and perceived as two different objects inhabiting the same space at the same time.

The Paradox Box exhibit not only misleads the observer's own intuition, it defies the laws of physics that say that two objects cannot occupy the same space simultaneously!

Attentional guidance by learned associations

Joy Geng[1]

[1]University of California, United States

Visual search is most efficient when the internal representation of the target is highly distinct from distractors in the sensory environment. When targets are hard to find, attentional guidance may rely instead on more visually distinct objects that are strongly associated with the target. These associated objects serve as predictive proxies for the target and increase the efficiency of target search. In this talk, I will discuss behavioral experiments examining the conditions under which attentional guidance switches from target features to predictive proxies and fMRI data showing that the hand-off of information about the target to the proxy occurs before search begins. Together these data suggest that attention is highly flexible and has access to target and auxiliary information when selecting features to guide attention.

A role for visual cortex in the priming of attentional selection

Jacob Westerberg[1]

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Visual search for conspicuous objects is anything but static. Notably, search for the same conspicuous feature becomes more efficient with repetition. Take for instance priming of attentional selection (e.g., priming of pop-out). Searching for a salient red object leads to faster and more accurate identification of subsequent salient red objects. We investigated the neural circuits and concomitant processing dynamics promoting these behavioral improvements. Monkeys performed a color-based priming of pop-out task while neural activity was recorded across the layers of visual cortical area V4. V4 is a mid-level sensory area with robust feedforward connections as well as notable modulation during attention tasks. Two key observations became apparent. In observing cross-laminar spiking activity, neuronal target selection and distractor suppression both were stronger with priming but manifested differently across both spatial and temporal dimensions. This indicates that the changes to target enhancement and distractor suppression involve distinct neural mechanisms which could operate

independently. Next, we found that attentional selection in this task manifested bottom-up regardless of the state of priming. However, this bottomup selection is biased towards behaviorally pertinent features, as encouraged through priming, through modulation of cortical feature maps. Specifically, cortical columns preferring red had elevated ongoing spiking activity during repeated search for the red objects which subsided when search for green became the objective. Taken together, these findings outline a mechanism for priming of attentional selection and moreover suggest a dominant role for sensory cortex in enabling the associated behavioral changes.

The effect of ongoing phase activity on visual perception

Shen-Mou Hsu[1]

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In addition to ongoing power, which might manifest the fluctuations of internal criteria for instance, the phase of rhythmic brain activity is also thought to be central to organizing perceptual processing given that it may provide a recurrent temporal frame for information coding. Understanding the functional significance of the phase so as to regulate its behavior may benefit visual perception. To investigate to what extent the fluctuations in perception could be directly ascribed to the rhythmic phases, we employed the real-time phase-locked stimulus presentation approach and found that early interaction between parietal peristimulus alpha phases and incoming stimuli orchestrated the neural representation of the fate of the stimuli. This neural representation varied according to the phase and in turn shaped the behavioral outcomes during visual detection. Our studies further showed that phase activity could be adjusted by the slow- relative to normal-paced respiration across breathing cycles in a structured manner over widespread brain areas. Moreover, such adjustment could modulate the perceptual sensitivity during emotion perception as mediated by cross-frequency phase-amplitude coupling. Overall, we suggest that how stimuli are differentially processed as a result of a stimulus-phase interaction plays a contributing role in determining the perceptual fate of incoming stimuli. Through a volitionally controlled change in respiration, we might be able to systematically regulate phase activity and in turn, alter our perceptual processes.

Identifying and managing multiple time scales in perception

Pascal Mamassian[1]

[1]Ecole Normale Supérieure, Paris, France

There is a wealth of evidence that past sensory experience is affecting what we perceive now. This evidence is coming from a variety of experimental paradigms, including sequential effects in simple sensory discriminations, adaptation and aftereffect measurements, postcueing target detections, and implicit learning of statistical regularities. These different experiments typically lead to different time scales of history effects in perception, and it is not clear whether these different time scales are merely the result of the observers being

engaged in different tasks. An alternative possibility is that these multiple time scales coexist. In this presentation, I will present the challenge of experimentally identifying multiple

time scales in a single experiment, and compare different types of analysis. I will also discuss the challenge for the visual system to manage these different time scales to ultimately produce a robust percept.

How is probability represented over time?

Arni Kristjansson[1]

[1]University of Iceland, Iceland

Attentional priming has a dominating influence on vision, speeding visual search, releasing items from crowding, reducing masking effects, and during free-choice, primed targets are

chosen over unprimed ones. Such history effects are arguably even more dramatic for distractor sets on these tasks. Templates stored in working memory are assumed to control attention and mediate the priming. But what is the nature of these templates? Real-world visual scenes suggest that tuning templates to exact color or luminance values would be impractical since the real world can vary greatly because of changes in environmental illumination and perceptual interpretation. Tuning templates to a range of highly probable values might be more efficient. Can the visual system represent such probability, that is picked up over time? Recent evidence suggests that the visual system gradually encodes statistical variation in the environment through repeated exposure to input statistics. I argue that such probabilistic representations are the unit of attentional priming and that priming of, say, a repeated single-color value simply involves priming of a distribution with no variance. This is consistent with evidence from neurophysiology and theoretical neuroscience as well as computational evidence of probabilistic representations in visual perception. Such "priming of probability" can be modelled where priming provides

contextual priors and can be thought of as learning of the u derlying probability density function of the target or distractor sets.

Word, face, and object recognition in posterior stroke: Patterns of performance and underlying lesions

Randi Starrfelt[1]

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Acquired reading deficits (alexia) can follow damage to posterior brain regions, in particular in the left hemisphere, and may occur in isolation or in the context of other visual deficits like object or face agnosia. Typically, studies of alexia have relied on single cases or case series of patients recruited based on the presence of a specific reading deficits. In the Back of the Brain-project (BoB), patients were recruited based on lesion location in areas supplied by the posterior cerebral artery, rather than the presence of particular symptoms. Thus, the sample includes patients (N=65) with and without reading deficits, in addition to a healthy control group. I will present the patterns of deficits seen in this sample across the different visual categories (words, faces and objects), and how these relate to underlying lesions. Behaviourally, most patients showed general deficits across categories (n=22) or no deficits at all (n=21). Category-selective deficits were rare (n=6), and were only found for words. Interestingly, behavioural impairment in all domains was observed following unilateral left and right as well as bilateral lesions. However, the regions most strongly related to reading performance mainly confirmed the pattern reported in more selective cases, and included a left hemisphere cluster extending from the occipital pole along the fusiform and lingual gyri. While the findings provide support for specific, left lateralized brain regions being critical for visual word recognition, the results also suggest that both hemispheres are involved in the visual processing of words, faces, and objects.

The role of visual shape processing in skilled reading

Alan C. Wong[1]

[1]University of Surrey, United Kingdom

For a skill as complex as reading, multiple factors are likely to explain its success and failure. The role of visual shape processing in reading has been largely overlooked, yet more studies are suggesting its importance. It has long been established that expertise in reading is associated with engagement of specialized regions in the ventral visual pathway for object processing. A number of visual phenomena have also been linked with skilled reading. For example, holistic processing was found to be larger for native than non-native English readers, and for Chinese than non-Chinese readers. In normal Portuguese readers, holistic word processing was shown to be correlated with faster lexical decision. Sensitivity to configural information in words has also been shown for expert English and Chinese readers, and was correlated with expertise in Chinese word reading. In addition, visual crowding with musical notation was reduced with music-reading training. Our recent work showed that in Chinese children with developmental dyslexia, fluency in visual matching of characters significantly predicted speeded and non-speeded word reading performance on top of factors like age, non-verbal IQ, phonological awareness, morphological awareness, rapid automatized naming, and visual digit matching. In music sight-reading, performance of intermediate-to-advanced musicians were largely explained by fluency in visual matching of musical notes as well as visual-auditory and visual-motor abilities. Looking into the future, the extent to which visual shape processing contributes to reading for different writing systems has important implications in literacy development and intervention.

Dyslexia in Chinese word recognition - What do its (dis-)similarities with face-recognition tell us?

Ricky Tso[1]

[1]The Education University of Hong Kong, Hong Kong

Expert face recognition has long been marked by holistic processing and right-hemispheric lateralization. Hence, due to the many visual properties shared between face perception and Chinese characters, it has been suggested that Chinese character recognition may share similar underlying cognitive processes with face recognition. In this session, we will examine two common face recognition perceptual phenomena – holistic processing and left-side bias – in Chinese character recognition in people with developmental dyslexia. Studies on how the special populations perceive Chinese characters may perhaps give insights into the analogies and (dis-)similarities between the underlying cognitive processes in Chinese character and face recognition. Implications on how these findings further enhance our understanding of cognition in the special population will be discussed.

Disrupted neural mechanisms of high-level vision and their role in reading problems

Heida Maria Sigurdardottir[1]

[1]University of Iceland, Iceland

According to our high-level visual dysfunction hypothesis, one potential causal factor in developmental dyslexia is disrupted functioning of high-level visual mechanisms that support the recognition of words and other objects. Evidence comes from studies which indicate that people with dyslexia have specific problems with discriminating and recognizing not just words but also other visually presented objects. The reading problems of some dyslexic readers might thus be a salient manifestation of a more general high-level visual deficit. In this talk, I will highlight some of this work with a focus on our preregistered project (https://osf.io/4dr3f) where we put the hypothesized deficient neural processing of visual objects in dyslexia to a direct

test. We use electroencephalography (EEG) to map neural tuning of dyslexic and typical readers to objects and compare to behavioral measures of high-level visual functioning. Our results suggest that dyslexic readers show functional neural abnormalities that reflect problems with high-level visual mechanisms.

Cognitive vs. visual responses to numeral representations of parity with EEG

Talia Retter[1], Lucas Eraßmy[1], Christine Schiltz[1]

[1]University of Luxembourg, Luxembourg

The concept of parity, assigning integers into categories of even and odd, may rapidly and automatically be invoked in our perception of numbers. Electroencephalogram (EEG) provides a promising technique for probing automatic processing of numerical concepts, such as parity, without a related numerical task. However, the extent to which EEG responses to symbolic numbers are affected by lower-level visual stimulus attributes remains largely untested. To investigate automatic responses to parity, we used an EEG frequency-tagging approach in which sequences of Arabic numerals (2 – 9) were presented at 7.5 Hz; importantly, odd and even numbers were alternated (at 7.5/2=3.75 Hz), so that if asymmetrical responses differentiating odd and even numerals were present, this would be captured at 3.75 Hz. Parity responses were probed with four different stimulus sets, differing in their lower-level visual compositions. Moreover, two control conditions were tested for each stimulus set, comprised of non-conceptual numeral alternations (e.g., 2,4,5,7 vs. 3,6,8,9). Significant asymmetrical responses at 3.75 Hz were found to all stimulus sets and conditions over the occipitotemporal cortex. Significant differences across conditions were found for two stimulus sets: 1) the stimulus set with the least variability (one font) produced the largest responses for one of the control conditions; and 2) the stimulus set with the most variability (20 hand-drawn, colored exemplars per numeral) produced the largest responses to parity. These findings suggest that automatic responses to parity can be measured with EEG, although they can be strongly influenced by visual differences across small sets of Arabic numerals.

Number selective sensorimotor channels derived from individual differences

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Many psychophysical and physiological studies point to the existence of a sensorimotor number

system, which integrates numerical information from the environment with that internally

generated through actions. Here we studied the tuning of the sensorimotor number system with a

covariance analysis approach, based on individual differences and previously exploited to describe

sensory channels in human for the perception of contrast, spatial frequency, or motion. Participants

repeatedly pressed a key 8 to 32 times (to match a visual digit number), rapidly or slowly and

without counting. Reproduction precision (Weber fraction) was then correlated between

participants. As similar intensity values are expected to partially share the same channel, higher

correlations were expected for adjacent target numbers, compared to numerically distant targets.

As predicted, we found high positive correlations for nearby numbers, scaling down as a function of

numerical distance, implying tuning selectivity. Factor analysis identified two factors, one for low

(N8□14) and the other for higher numbers (N14□32) and a Principal component analysis revealed

two clear bell-shaped covariance channels tuned to different numerical values (~11 and ~27). Finally,

two control conditions ruled out the influence of non-numerical strategies based on responses

duration or average temporal frequency. Overall, these results are the signature of dedicated

systems in charge of mapping sensory inputs into sequences of number-actions.

The pupil reflects perceived numerosity after adaptation

Camilla Caponi[1], Elisa Castaldi[1], David Burr[1], Paola Binda[2]

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Although pupil size is modulated mainly by luminance, previous studies have shown that many other factors can regulate pupillary constriction and dilation, including numerosity. We recently reported that even without an explicit numerosity task, the pupil light response scales with the numerosity of the evoking light or dark stimulus, with the response gain increasing with increasing numerosities. Here we show that after adaptation, pupillary gain scales with the perceived rather than physical numerosity. Fifteen participants adapted separately to low (n=10) and high (n=160) numerosities of dots, with dot-size varying to keep total area (hence luminosity) constant. Stimuli were designed to keep luminance constant across conditions,

by reducing average dot-size with increasing numerosity. Within-stimulus size-variance was introduced to dissociate numerosity and individual dot-size and produce small luminance differences across stimuli; these allowed us to quantify numerosity (adaptation) effects on the pupillary light response as the equivalent luminance increment.

We found that during the adaptation phase, pupillary constriction was stronger to high- than low-numerosity stimuli, despite the large difference in individual dot size, expanding previous findings to size invariance. During the test phase, the pupillary constriction to identical physical stimuli (10 – 40 dots) was weaker after adaptation to high- than to low- numerosity, consistent with the response being regulated by the perceived numerosity after adaptation (verified psychophysically). These results reinforce our previous report that the gain of the pupillary light response is modulated spontaneously by numerosity, and further show that it is the perceived, not physical numerosity driving the gain control. This is clear evidence that numerosity adaptation affects sensory mechanisms (rather than causing a response bias), detectable by the pupillary light response. Taken together the experiments show that numerosity is a spontaneously coded visual feature that can modulate one of the most simple and automatic physiological responses.

Computational and empirical for time's subjective expansion in temporal oddball paradigm using recurrent neural network

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Temporal oddball paradigm has been used by Tse et al. (2004) to demonstrate attentional involvement in time perception by focusing on the time's subjective expansion (TSE) elicited when the participants judged temporal persistence interval of the oddball compared to the other constituent displays in the stream. In the current work we set out to show that a simple decision mechanism implemented as winner-take-all (WTA) on a recurrent on-center off-surround neural network can exhibit TSE as a by-product of the neural computation. As temporal oddball paradigms are judged by two-alternative forced choice (2AFC) task regarding whether the oddball or standard duration was longer, we modeled the phenomenon as WTA competition between two nodes to determine the `winner'. Employing a simple assumption that novelty/surprise

of oddball display can be captured by higher clamping level, allowed us to replicate most of the experimental findings in temporal oddball phenomena. We also corroborate the model predictions using a behavioral experiment of temporal oddball using visual and auditory modalities. The results of behavioral experiments are in line with model predictions.

Do deviants in irrelevant sound sequence disrupt visually presented arithmetic task?

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Two types of disruptive effects of irrelevant sound on visual tasks have been reported: the changing-state effect and the deviation effect. The idea that the deviation effect is not specific to the task nature, whereas the changing-state effect is specific to tasks that require serial processing, has been examined by comparing tasks that do or do not require serial processing. While many previous studies used the missing-item task as the non-serial task, it is unclear whether other non-serial tasks lead to similar results as to the differences in task specificity of both effects. One of the recent studies used the mental arithmetic task as the non-serial task, but failed to show the deviation effect. There were, however, some procedural and cognitive-control factors that could explain the lack of deviation effect in the mental arithmetic task, as the design and procedures were somewhat different (e.g. conducted online, intermixed conditions). Also, the cognitive load of the task (1-digit addition/subtraction) may have been too low to induce the deviation effect. The present study tested such possible factors. Experiment 1 examined the procedural differences. Stimulus presentation and experimental design were set similar to those in the study that showed the deviation effect (e.g. conducted face-to-face, testing conditions in separate blocks), but no deviation effect was found. Experiment 2 examined the effect of cognitive load, but no deviation effect was found even when the task load was high (2-digit addition and subtraction) and the task performance was deteriorated. These results demonstrate that the lack of the deviation effect is not likely explained by the confounds of the experimental design or the task load, and cast doubt on the assumption that the deviation effect is generally found in non-serial tasks.

Investigating the neural correlates of numerosity adaptation through EEG single-trial decoding

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The neurophysiological underpinnings of numerosity adaptation are not fully understood. We investigated whether the EEG response to an adaptor modulates the neural response to a test stimulus in accordance to observable behavior. We designed a

two-adaptor configuration for a numerosity judgement task, one with a real adaptor (a stimulus more numerous than the test) and one with a neutral adaptor (matching the numerosity of the test). The two adaptors appeared concurrently in diametrically opposite locations and preceded the appearance of the test stimulus which alternatively fell in one of the two adapted positions. At the behavioral level, test stimuli displayed at the numerous-adaptor location were underestimated by ~20%, while test stimuli appearing in the location of the neutral adaptor remained veridical.

We trained decoders to classify adaptor configurations on EEG filtered in the alpha range (8–12 Hz) and evaluated their performance on the test stimulus signal. The adaptor signal could be decoded in the response to the test stimulus, showing that a trace had remained. Specifically, when the test stimulus was displayed at the real adaptor location, the adaptor signal increased, but decreased in trials when the test appeared at the neutral adaptor location. The strength of the adaptor signal correlated with the strength of adaptation across observers in adapted trials, but not for neutral-adapted trials. This pattern was confirmed at the single-trial level, suggesting that the echoing activity of the adaptor might induce the behavioral adaptation effect.

Our data suggest that numerosity adaptation may be driven by the reactivation of a perceptually distant stimulus (adaptor) which impacts the processing of the novel (test) stimulus. These results are in line with prior-updating mechanisms such as norm-based coding, where perceptual responses are biased away from average statistics.

What is the minimum duration for grouping to occur? The example of crowding

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In crowding, perception of a target deteriorates by the presence of nearby flankers. Classically, low-level neural mechanisms, such as pooling, substitution, and lateral inhibition were proposed to explain crowding. However, these mechanisms cannot explain that, for example, adding more flankers can undo crowding. These uncrowding effects occur only when the flankers group together and, thus, the target ungroups from the flankers. Here, we show that such grouping mechanisms occur in a time consuming process. Participants were asked to discriminate the offset of a vernier presented alone or flanked by lines, rectangles, or cuboids for either 20 ms or 160 ms. For a 160 ms stimulus duration, strong crowding occurred with flanking lines. For rectangles and cuboids, we found much better performance even though the lines were contained in the rectangles/cuboids. For a 20 ms stimulus duration, strong crowding was observed for all stimuli indicating that grouping needs longer durations than 20 ms. We carried out a second experiment with further surprising results: when the cuboids were presented without the vernier for 20 ms, followed by an Inter Stimulus Interval of 120 ms, and followed by the display with the cuboids and the vernier, strong un-crowding occurred. Hence, showing the cuboids without the target for 20 ms was as good as presenting cuboids and target together for longer durations. The same was not true for the presentation of cuboids with the vernier, followed by the cuboids without the vernier and for any of the conditions with lines. Taken together, our results show that crowding is as much as a temporal as a complex spatial phenomenon- something all standard models of crowding miss.

Can optical size manipulations improve time-to-contact estimation of accelerating vehicles?

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The objective of this study is to investigate if adjusting the optical size of a vehicle can reduce errors in time-to-contact (TTC) estimation for an accelerating vehicle. Previous research has shown that observers fail to account for accelerated approaches. It has also shown that increasing the optical size of an object shortens TTC estimates (size-arrival effect). Can we capitalize on this effect? We conduct a laboratory study using a motion prediction paradigm to investigate how adjusting the optical size influences the TTC estimation.

Participants look into a rear-view mirror and see a vehicle approach for two seconds before it is occluded. They are asked to estimate the time it takes the vehicle to reach the participants' position based on its current speed and acceleration. The optical size of the vehicle is synched to its acceleration. We vary acceleration rate (positive, negative acceleration, or constant velocity), magnitude of the size enhancement, distance and velocity of the vehicle at the moment of occlusion.

We hypothesize that adjusting the optical size according to the acceleration of a vehicle reduces errors in time-to-contact estimation. This way, the size-enhanced mirror image could reduce the likelihood of accidents due to inaccurate TTC estimates and therefore improve road safety. The enhancement could be implemented in camera-monitor systems, which are becoming more and more common.

Pre- and post-sensory effects on velocity judgements

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It has long been known that previous sensory information affects current sensory experience, playing a part in maintaining temporal constancy in perception. In experimental paradigms, this has been quantified in effects such as priming and serial-dependence. But post-sensory information also affects the judgement of previous sensory experience. For example, Loftus, Miller & Burns (1978), showed how verbal information, following visual presentation, altered the judgement of that experience. In the real world, such effects presumably work together to help us build a coherent and stable judgement of an ever-changing and noisy sensory environment. But what happens when these two effects are incongruent? In this experiment, a disk moved at a constant velocity (that varied between trials) across a screen before disappearing behind a screen. While the screen occluded the disk an engine sound (varying in dB) was played. After each trial participants performed an adjustment task adjusting the speed of a ball to match the speed of the previously seen ball. The velocity of the disk in the previous trial served as the pre- sensory stimulus and the sound playing after the disk disappeared served as the post- presentation stimulus. As expected, main effects of previous trials and post-presentation information were found. The most interesting results come from the interaction between the two, both when they were congruent (both affecting the judgement in the same direction) but especially when they are incongruent (each affecting the judgement in opposite directions). The results indicate that these effects should not be looked at in isolation, especially when they are generalized to real-world perception where both pre- and post-information are abundant.

Space & Time in Binocular Vision

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Introduction: Binocular summation (BS), defined as the superiority of binocular over monocular visual performance, shows that thresholds are about 40% (factor 1.4) better in binocular than in monocular viewing. However, it was reported that different amounts of BS exist in a range from 1.4 to 2 values because BS is affected by the spatiotemporal parameters of the stimulus. Lateral interaction can be defined as the neuron's ability to affect the neighboring neurons by inhibiting or exciting their activity. The perceptive field (PF) is the fundamental processing unit of human vision; both masking and crowding depend on its size. We investigated the effect of the spatial and temporal domains on BS under the lateral masking paradigm and how BS would be affected by both lateral interaction and the PF's size via a lateral masking experiment.

Methods: The two temporal alternative forced choice (2TAFC) method was used. The stimuli consisted of a central vertically oriented Gabor target and high-contrast Gabor flankers positioned in two configurations (orthogonal or collinear) with target-flanker separations of either 2 or 3 wavelengths (λ), presented at 4 different presentation times (40,80,120, and 200ms) using a different order of measurements across the different experiments. Opaque lenses were used to control the monocular and binocular vision.

Results: BS is absent at close distances (2λ), depending on the presentation time's order, for the collinear but not for the orthogonal configuration. However, BS exists at more distant flankers (collinear and orthogonal, 3λ). We found a strong correlation between the suppression zone and the PF's size for both monocular and binocular vision.

Conclusions: BS is not uniform (1.4); it depends on the stimulus condition, the presentation times, the order, and the method that was used to control the monocular and binocular vision.

The Effect of Time Pressure on Visual Search Strategies in Dual Search Tasks

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When searching for an object, it is not uncommon to interrupt our initial search to look for something else. For instance, we might abandon our search for car keys and start searching for a bus pass instead because we are running against the clock to avoid being late for an appointment. Despite its prevalence in everyday life, research on that topic is scarce. In the current experiment, we investigated the effect of varying levels of time pressure on a multiple-target search task. To this end, we conducted an eye-tracking experiment in which 24 participants performed two consecutive, time-limited searches for a target letter in two different displays of 15 items. Furthermore, when searching under time pressure, participants had the option of self-interrupting their first search in order to move on to the second one. The results showed that, as time pressure increased, search accuracy decreased. Moreover, we observed that participants rarely utilized the self-interruption. Instead, they prioritized a thorough initial search until target acquisition, and if they had any spare time left, they would proceed to the second search as a secondary priority. Overall, our findings suggest that time pressure negatively affects dual visual search tasks, and specifically, when both searches are of equal value, the first search becomes prioritized.

Time estimation during motor activity

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Several studies on time perception have shown that paying attention only to time induces temporal overestimation. Instead, diverting attention away from time, as when executing demanding cognitive tasks, causes time underestimation (attentional allocation model). Some studies also found that temporal judgments are affected by motor processes. What remains unclear is how motor and cognitive tasks interact and influence time perception.

In this study, we investigate time estimation of long durations while simultaneously performing cognitive and motor tasks, as often happens in everyday life conditions.

In the first experiment, we tested prospective verbal time estimation during the execution of four cognitive tasks of increasing difficulty (look at the screen, read and solve simple or hard mathematical sums) while sitting or walking on a treadmill. In both motor conditions, we find temporal overestimation while fully attending to time and temporal underestimation during mental tasks, increasing with cognitive load. Walking induces a larger underestimation, with higher uncertainty, only during demanding cognitive tasks. In the absence of other concurrent tasks, we find no effects of walking on time estimation, maybe due to its automaticity. We hypothesize that a more difficult motor activity might need allocation of attention per sé, and therefore might affect temporal estimation with increasing distortions as a function of its difficulty.

In the second experiment, we then tested the effects of three types of walking (forward regular-speed, forward irregular-speed, and backward irregular-speed walking) on time estimation, in the absence of a concurrent cognitive task. Our results do not show any evidence of differential effects induced by walking difficulty on temporal perception.

In conclusion, walking seems to divert attention only when combined with other cognitive tasks, whereas it does not seem to require allocation of attention influencing time perception per sé, as other cognitive tasks do, even when it is highly demanding.

Trial-by-trial feedback fails to improve the consideration of acceleration in visual time-to-collision estimation

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Untrained individuals who judge the time-to-collision (TTC) of visually presented accelerating vehicles tend to solely rely on first-order information (velocity) of the vehicle and do not appropriately account for its second-order information (acceleration). Thus, they estimate the TTC of the vehicle as if it were traveling at a constant velocity. This results into erroneous overestimation of the TTC for accelerating vehicles, which can potentially lead to unsafe road-crossing behavior for pedestrians in traffic situations. This study aimed to investigate whether training with trial-by-trial feedback about the difference between estimated and actual TTC ("knowledge of results") could reduce TTC estimation errors for accelerating vehicles. The experiment utilized a prediction-motion paradigm to evaluate the estimated TTCs of twenty participants for both constant-velocity and accelerated vehicle approaches in a VR traffic simulation, from a pedestrian's viewpoint. The second block of the three experimental blocks provided trial-by-trial feedback regarding TTC estimation accuracy. Although participants generally adjusted their estimations during and after the feedback (block 2 and 3), they failed to distinguish between accelerated and constant-velocity vehicle approaches, as was also observed in the first block (without feedback). Thus, the feedback did not aid in accounting for second-order information. This suggests that a safety training program including trial-by-trial feedback is unlikely to be an effective solution to counteract pedestrians' TTC estimation errors for accelerating objects.

The role of perceptual novelty in the temporal oddball effect

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A novel sensory event (oddball) appears to last longer than previously experienced ones. Studies have demonstrated that changes in various visual features induce this subjective expansion of time, which is known as the temporal oddball effect. However, it is not yet clear whether the physical change or perceptual novelty of the visual event is important for this effect to occur. To address this question, we examined the effect of perceptual novelty on the temporal oddball effect by using the Thatcher illusion: local changes in facial features are hardly recognisable when presented inverted but not upright. In the first

experiment, we presented a Thatcherised face, whose eyes and mouth are inverted locally, as an oddball stimulus after repeated presentation of an intact face. Participants compared the durations of the faces presented in the last and penultimate positions of the sequence. The results showed that the oddball stimulus was perceived to last longer when the faces were presented upright compared to inverted. To rule out the possibility that the effect could be due to the difference in repetition suppression between upright and inverted faces, we conducted the second experiment, in which the same intact faces were repeatedly presented either upright or inverted. The results showed no significant difference in the duration distortion and thus rejected the above possibility. Our findings emphasise the importance of perceptual novelty in the temporal oddball effect and further support the idea that high-level visual stages, which are involved in the configural information processing, may be important for the temporal oddball effect.

Perceptual processing speed depends on size, but not numerosity or objecthood

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Some visual information appears to reach perception faster than other. For example, the onset of a large stimulus is perceived later than the onset of a small stimulus (Kanai et al., 2017), and the representation of a smaller number of dots in a numerosity stimulus seems to take less time than that of a larger number of dots (Cheyette & Piantadosi, 2020). I explicitly tested visual processing speed differences, as the time that visual information needs to reach perception or initiate action, for a range of stimulus categories. I used three different stimulus categories that varied in one dimension each: disks that varied in size (diameter of 2 and 6 degrees of visual angle), numerosity stimuli that varied in the number of dots contained (4 and 12 dots), and object images that varied in recognisability (intact image and phase-scrambled version). To compare the impact of these variations in each category on perceptual detection vs. action initiation, participants performed two tasks: (1) a temporal-order judgement task, in which participants indicated which of two stimuli appeared last, and (2) a saccade task, in which they saccaded towards a single stimulus as fast and accurately as possible. In the temporal-order judgement task, I found that the onset of a large disk was indeed perceived later than the onset of a small disk. For the other two stimulus categories, however, there were no differences in perceived onset between the stimulus variants. In the saccade task, I found image stimuli to yield the shortest saccade latencies but there were no differences between stimulus variants. I conclude that the time for visual information to reach perception varies with stimulus size, but not with numerosity or objecthood of image content, and that action initiation speed is distinct from perceptual detection speed.

Acknowledgements:

Supported by European Research Council (grant No 865715) and Deutsche Forschungsgemeinschaft (grants RO 3579/8-1 and RO 3579/12-1) granted to Martin Rolfs.

The influence of scene violations and attention on timing

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Real world object arrangement is very specific and governed by a few rules. These rules are relevant to the spatial relations among objects and scenes (i.e., syntactic rules) and to their contextual relations (i.e., semantic rules). It has been previously observed that by violating semantic rules, duration perception of scenes is dilated. Yet, no investigation to-date has looked at the role of syntactic violations on time estimation. Furthermore, it has yet to be determined whether the effect of scene violations on timing stems from attentional or other cognitive accounts. We, thus, utilized an oddball paradigm and real-world scenes with or without semantic and syntactic violations in two experiments investigating whether time dilation will be obtained in the presence of any type of scene violation and the role of attention in any such effect. Results from Experiment 1 showed that time expansion in the presence of syntactic violations, while the opposite occurred in the presence of the semantic ones. In Experiment 2, a contrast manipulation of the target "odd" objects was utilized to further investigate whether the expansion noted in Experiment 1 was driven by attentional accounts. The results showed that, indeed, an increased contrast can lead to interval overestimations for scenes with syntactic as well as semantic violations. The results from our study suggest that both semantic and syntactic violations affect timing yet in a different way due differences in their processing. Moreover, attentional manipulations (i.e., target objects' contrast increase) influence their effect on timing.

The Role of Top-Down Attention in Shape from Shading

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The ability to perceive three-dimensional objects is a fundamental aspect of typical human vision, yet how the visual system utilises monocular cues to create three-dimensional

objects from two-dimensional retinal input remains largely unexplored. We explore this question in the context of shape from shading, referring to the perception of a three-dimensional shape due to the shading pattern of an object. Shape from shading has previously been described as a pre-attentive process that occurs in parallel across the visual field. However, recent research has challenged this notion, suggesting that shape from shading involves two distinct processes. Specifically, an early stage that is responsible for object segregation from the background, operating in a pre-attentive manner, and a later stage which utilises top-down attention to identify three-dimensional shape. To investigate this proposal, we measure event-related potentials whilst participants passively or actively view three-dimensional or two-dimensional objects. It is hypothesised that passively viewing three-dimensional objects will significantly affect early event-related potentials (P1/N1) compared to passively viewing a two-dimensional control stimulus. In contrast, active, rather than passive viewing of three-dimensional objects, will significantly modulate later event-related potentials (P2/N2). Moreover, the difference in event-related potentials between passive and active viewing conditions will be greater for three-dimensional than two-dimensional objects, suggesting that the modulation of event-related potentials is due in part to three-dimensional processing, and not due to attentional effects alone. This study will aid in providing insight into the underlying cognitive processes that are required to perceive three-dimensional objects.

Voluntary eyelid movements facilitate perceptual alternation of bistable apparent motion

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We showed that voluntary eyelid movements, i.e., blinking and opening more widely, facilitate perceptual alternation during continuous flash suppression (Sato & Kimura, VSS 2020). This study aimed to investigate the generality of this finding in two ways: whether the facilitatory effect could also be found in bistable apparent motion (other multistable perceptions), and whether voluntary key pressing (other voluntary actions) could also facilitate perceptual alternation. The bistable apparent motion was created by alternating frames with two diagonally aligned dots (0.5 deg in diameter) at 5 Hz. The horizontal to vertical distance ratio (aspect ratio) of the dots was gradually changed from the horizontally or vertically biased configuration to a square configuration over 4.2 seconds and then to the opposite configuration over 4.2 seconds. Thus, the perceived motion direction was fixed (horizontal or vertical) at stimulus onset and then altered to the other direction at some point by changing the aspect ratio. The time required for perceptual alternation was measured as the time of alternation (TOA). Results showed that the mean TOAs were shorter when voluntary blinking or eyelid opening was conducted in response to a visual cue. Moreover, the perceptual alternation occurred in a time-locked fashion, i.e., mostly around 1.0 seconds after the cue. These findings indicate that voluntary eyelid movements facilitate perceptual alternation. However, voluntary key pressing did not modulate TOA. Thus, the facilitatory effect seems specific to eyelid movements. Furthermore, a physical blackout, which was presented by darkening the entire stimulus display, and spontaneous (unintentional) blinking did not affect TOA. These results suggest that physical changes in visual input associated with blinking were not the main cause of the facilitation. These findings confirm and extend our previous findings with continuous flash suppression and suggest that extra-retinal processing associated with voluntary eyelid movements facilitates perceptual alternation.

Are you walking in my direction? Brain responses to different directions of motion – an fNIRS study with point-light walkers

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One of most extraordinary human abilities is to understand other's people behaviors simply by looking at their movements. Humans are so skilled at perceiving, detecting and understanding the motion of others that one brain area seems to be particularly sensitive to the perception of biological motion: the right posterior Superior Temporal Sulcus (rpSTS). The rpSTS is activated by the perception of human motion even when subjects only see a few dots attached to the major joints of a moving body (i.e., a point-light display). However, most of studies investigating biological motion perception employed point-light displays presented on a lateral view, thus, not facing the viewer. Very few studies investigated if the presentation of different directions of motion affects our response to point-light walkers. The rpSTS is central node of the social brain network thus we hypothesize that a walking approaching person, facing the viewer and potentially aiming to interact, might elicit stronger responses in this region.

Using fNIRS we measured right and left pSTS responses to point-light walkers presented in four different viewpoints and translating in four directions: (1) frontal, approaching the viewer; (2) backwards, moving away from the viewer; (3) right-lateral, walking from left to right; and (4) left- lateral, walking from right to left.

Subjects (N=27) in our study were asked to passively watch both coherent and scrambled versions of the point-light displays walking in the four directions while their brain activity was recorded (block design). A static image of the displays was used as baseline.

Our preliminary analysis showed that the rpSTS preferentially responds to the coherent displays in relation to the scrambled ones, replicating previous findings. Moreover, the frontal approaching coherent point-light walker elicited a stronger response in rpSTS; this response was specific to the coherent frontal display and was not associated with the scrambled version of this display.

This study was supported by FCT (PTDC/PSIGER/5851/2020) and Bial Foundation Grants Programme (G-29863).

The experience of attractiveness, health and youthfulness of the female body: Effects of femininity of body shape and gait

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Previous studies show that men experience the typical feminine ("hourglass") body shape as the most attractive. In the present study, we tested two hypotheses regarding this preference. (1) The hourglass shape is attractive because it gives the impression of a healthy and young female person at her reproductive peak. (2) In order to increase their attractiveness, women can additionally enhance their femininity using dynamic means such as the feminine walk. In our experiment, 45 male participants rated 4 female avatars on the Attractive-Unattractive, Healthy-Sick and Young-Old scales. Stimuli (avatars) were generated using the DAZ 3D software. The body structure of avatars was scaled from low to high femininity: the lower the waist-to-hip ratio and the larger the breasts and buttocks, the higher the body femininity. The avatars were presented in two dynamic conditions – a neutral and feminine walk (catwalk). The main effects of body femininity, as well as gait femininity were significant for all dependent variables. Ratings formed inverted U-shaped plots with the peaks at medium levels of femininity and the lowest values at the lowest and highest levels of femininity. The plots for attractiveness and health were symmetrical, while the youthfulness curve was asymmetrical – more feminine avatars were rated as older than less feminine ones. Similar differences were also obtained in regression analysis, which showed that attractiveness can be better predicted by health than by youth. Finally, a feminine gait raised the ratings by making the avatars more attractive, healthy and youthful. These results showed that (1) the experience of attractiveness was more closely related to the impression of a healthy than a youthful appearance, (2) the most attractive, healthiest and youngest looking bodies were at medium levels of femininity, and (3) all ratings increased with more pronounced feminine dynamics (catwalk).

Neurodynamical model of dynamic bodily action recognition

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For social species such as primates, the recognition of dynamic body movements is important for survival. The detailed neural circuitry underlying the visual processing of dynamic bodies is not well understood. In monkeys, it is known that different body patches in the monkey cortex contribute to this processing.

We present a physiologically-inspired neural model of the visual recognition of body movements in comparison with electrophysiological data from macaque monkeys. The model combines an image-computable model ('ShapeComp', Morgenstern et al., 2021) that produces high-dimensional vectors describing the shape of objects (based on their shape boundaries as input), with a neurodynamical model (Giese & Poggio, 2003) that has successfully reproduced the neural dynamics at the single-cell level in higher areas of the visual and premotor cortex. The model recognizes videos of body silhouettes performing various actions.

The initial layers of the visual pathway that detect mid-level features are modeled by the ShapeComp network. This convolutional neural network architecture is trained using a GAN approach and represents the invariance properties of human shape perception better than other standard networks. The shape feature vectors of this network are used to train radial basis function networks which provide input to recurrent neural networks (neural fields) that encode sequences of keyframes (extracted from videos). The highest level of the model consists of motion pattern neurons that temporally summate the activity within individual neural fields that represent different body actions.

The model's responses were compared with macaque single-unit responses from the rostral dorsal bank of the Superior Temporal Sulcus (AMUB body patch) recorded for the same stimuli. The model successfully reproduces characteristics of real neurons at the population level. It also makes predictions about the dynamics of responses, e.g. in the presence of time gaps in the stimuli.

Acknowledgments:

ERC 2019-SyG-RELEVANCE-856495; HFSP RGP0036/2016; BMBF FKZ 01GQ1704, KONSENS-NHE BW StiftungNEU007/1; DFG GZ: KA 1258/15-1; SSTeP-KiZ BMG:ZMWI1-2520DAT700.

Prerana Kumar was also supported by IMPRS-IS.

Long-Duration Exposure to Microgravity Does Not Affect Perceived Travel Distance

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One of the most common, and most complex functions of the human brain is to perceive our own motion. Estimating how far we have travelled is a multisensory process, although the relative contributions from our different sensory systems in estimating travel distance is still unknown. Testing astronauts in microgravity not only allows us to parse out the contributions from the different senses more easily, but it can also inform mission planners and trainers about how our perception of travel distance might change in microgravity. Using virtual reality, we tested astronauts' (n=12, 6 female) perceived travel distance 5 times: once before their flight, twice in space (upon arrival and 3 months after), and twice again upon return to Earth (upon reentry and 2 months after). Results show no significant difference between the astronauts' estimations of travel distance after arriving to the ISS, after 3 months in space, or when they returned to Earth. These findings not only provide insights into the sensory contributions involved in making travel distance estimates, but also indicate that there is no adverse effect of long-duration exposure to microgravity on perceived travel distance.

The role of perceived naturalness and animacy in the visual pleasantness of a bouncing event

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The present research systematically explored the relationship between perceived naturalness, perceived animacy and visual pleasantness in bouncing events. Across two experiments, observers saw a small black disk moving back and forth repeatedly along the vertical axis of the screen. The following parameters were manipulated: (a) the simulated coefficient of restitution C (0.7, 0.85, 1, 1.15, 1.3), (b) the value of simulated gravitational acceleration a (9.81, 2.45, 0.61, 0.15 m/s^2), (c) the duration of the delay at the impact (0, 30, 60 ms) and (d) the motion pattern (uniform acceleration/deceleration or constant speed). There were three tasks, performed in three blocks in counterbalanced order. Observers used a VAS (Visual Analogue Scale) to judge (1) how much the animation looked as the bounce of a physical inanimate object, (2) how much the animation looked as the jumping of a living being endowed with its own force, and (3) how much the animation was pleasant and beautiful to see. We found that (i) C is negatively correlated with perceived naturalness and positively correlated with perceived animacy; (ii) perceived naturalness is enhanced by uniform acceleration/deceleration, whereas perceived animacy is (slighly) affected by the motion pattern; (iii) although a positive correlation between visual pleasantness and perceived animacy emerged, the two concepts are mostly independent from each other. Indeed, visual pleasantness was strongly affected by motion pattern (i.e., uniform acceleration/deceleration was judged as more pleasant than uniform velocity) and it was also partially affected by temporal delay, despite the fact that these parameters had little or no influence on perceived animacy.

Electrophysiological responses of the movement-related tactile gating in blindness

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The cortex suppresses or attenuates somatosensory information during the movement generated with an action. This phenomenon is known as movement-related tactile gating, and it has been suggested to be related to the generation of the efference copy (i.e., the internal representation of our movement) that allow us to discriminate which feedback belongs to the external world and which is generated by ourselves. Although it can lead to a worse encoding of tactile information, the diminished tactile feedback can be compensated through different strategies in typical individuals. Interstingly, vision seems to impact the phenomenon, with blind individuals showing reduced tactile reliability during active touch compared to its passive form. With this work, we wanted to shed some light on this issue by studying the neurophysiological responses using EEG in the time and time-frequency domains of sighted and blind participants in a tactile velocity discrimination task. Using a physical wheel, participants were presented on one fingertip with two movements that differed in speed and were instructed to detect the faster one. The experimental conditions were: (1) passive touch, where the finger of the participant was in a fixed position, and (2) active touch, where participants moved their finger contrary to the wheel's movement. Results suggest that vision modulates the difference of event-related electrophysiological responses in sensory-motor areas between passive and active touch. Our results are in agreement with the movement-related tactile gating. For this process to be successful, motor-

sensory and inter-sensory (i.e., cutaneous information, proprioception, and kinesthesia) must be correctly integrated. The failure of blind individuals to gate tactile information generated during movements may be due to the lack of multisensory processing between tactile and proprioceptive information.

Funded by EU H2020, MSC ITN 'MULTITOUCH', Grant Agreement No. 860114.

A new approach to the aperture problem in motion

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The aperture problem arises from the ambiguity of the motion of 1-dimensional pattern to a local analysis. Standard image gradient approaches compute 2-dimensional pattern motion by solving a set of over-determined linear equations, however this requires the inversion of a matrix, which is indeterminate (non-invertible) for 1-d pattern. In one recent model of human motion perception this is mitigated by introducing a constant on the matrix diagonal described as a slowness prior. However, this constant introduces space-variant error, as the magnitudes of the spatiotemporal derivatives change with location. An alternative, reformulating the geometry of the solution via Cramer's rule, will be described that provides a uniform result for plaids (2-d) and gratings (1-d). The second problem is that, at any point on a grating, measured speed over direction, described in velocity space, provides an infinite line avoiding the origin, and for a plaid it is a circle through the origin. A key step in generating an algorithm that is agnostic to the form of the spatial pattern is to consider a stereographic projection of velocity space. Grating motion projects to a circle through the south pole and plaid motion to a complementary circle through the north pole. A single biologically plausible algorithm using the slopes of the circles can compute the direction and speed for both gratings and plaids. The theory predicts neurons that respond well to plaids but not gratings, sometimes referred to as super pattern cells, which do not fit well into current theories of primate motion processing.

Acknowledgement: The research was supported by the Leverhulme Trust

The effects of naturalistic backgrounds and movements on judgements of motion

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Predators must distinguish the movements of their prey from their environment and other animals. Therefore, camouflaging one's motion, in both static and dynamic environments is valuable. Several motion camouflage strategies have been suggested to help prey evade predators. However, the effectiveness of these strategies has not been quantified. To fill this gap, our aim was to measure if the strategies are effective in an environment emulating natural motions. We started by creating a 3D-modelled database of moving forest scenes and prey movements. The database consists of variable landscapes, vegetation, composition, lighting, wind speeds, materials, scale, and viewing distances. Next, we measured human performance by asking participants to click a location to indicate perceived prey motion direction in short video clips. The videos consisted of static grey and moving forest scenes, displayed at 8° F.O.V and 60f.p.s. A small prey target moved in one of four motion patterns, inspired by motion camouflage strategies: (1) straight; (2) punctuated – prey stops and starts on a straight path to limit the predictability of motion; (3) sinusoidal; (4) zigzag – emulating 'protean motion' proposed to hinder location estimation. These were tested over 8 orientations and 2 environments (plain grey and moving forest). Both environment and motion type impacted motion estimation. Dynamic environments resulted in more variance in direction estimation than plain environments, across all motion types and orientations. Sinusoidal and zigzag motion produced greater systematic error and variance than straight and punctuated motion. Our work has begun to quantify how prey might have evolved motion to counter the exquisite motion detection abilities of many predator visual systems.

To what extent do attention and retinal location affect the optokinetic response?

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The optokinetic response (OKR) acts to stabilise fixation and consists of an initial slow-phase following eye movement and a rapid return movement in the opposite direction. The gain (ratio of slow-phase velocity to stimulus velocity) quantifies the extent to which the OKR matches stimulus motion. The dependence of gain on the size and location of motion in the visual field and role of attention remains unclear. Using random-dot-kinematograms (density 6 dots/deg^2; velocity 15 deg/s) we recorded OKR to horizontally moving dots confined to a circular central region that increased in area (radii ranging from 2.5 - 13.5 deg), or an equivalent large field (13.5 deg) where regions of increasing area were removed from the centre (inner radii ranging from 2.5 - 8 deg). OKR to a centre-surround configuration, where opposing motions were simultaneously presented to the centre and surround, was also investigated. Spatial attention to each region was manipulated using a counting

task, where observers (N=8) were required to report the number of times a subset of dots changed colour. Results showed that increasing the area of the central stimulus resulted in a rapid increase in OKR gain to ~0.9. Removing stimulus information from the centre produced a substantial drop in gain that was largely invariant of the area that was removed. For the centre-surround stimulus configuration, motion in the centre reduced gain to the opposing motion in the surround, and vice versa, but the OKR continuously alternated between following centre and periphery. Importantly, attention produced a general increase in gain of comparable magnitude (~0.1-0.2) across central and peripheral locations. These findings reveal that central and peripheral motion differ in the efficacy with which they can each drive the OKR, that central motion is not always prioritised when both are available and that spatial attention uniformly boosts OKR gain.

A hidden source of noise in techniques that yoke image motion to self-movement

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To study motion perception in activity-dependent contexts like virtual reality, researchers often yoke ongoing self-movement to the motion of objects and/or scene. The yoking can be defined by a 'motion gain' parameter that expresses the proportion of self-movement that is fed back into the display. Motion gain can then be manipulated across trials to determine various features of psychophysical performance, such as the motion gain needed to make the object or scene appear stationary, or the just noticeable difference between self-movement and object/scene movement. Motion gain is applied in real-time, which on the face of it should account for variations in self-movement. While this is true within a trial, when motion gain is varied psychophysically across trials, the average trial-by-trial variation in self-movement acts an external source of noise. Here we demonstrate two consequences. First, the psychometric function is no longer a single cumulative Gaussian because the standard deviation of the external noise varies with motion gain. The second, more obscure consequence is that when self-movement variability is quite high, the asymptotes of the psychometric function are reduced, which could be misinterpreted as an observer with a high lapse rate. Both consequences mean that fitting a psychometric function based on a single cumulative Gaussian will underestimate its slope. We explore various situations where this problem is maximised, especially those where images are most directly related to head rotation or translation. Examples include walking in virtual reality, head rotation with minimal eye movements, or situations where eye movements do not affect image formation, such as hearing. We develop a new psychometric function that takes account of this source of external noise and recovers the underlying performance of the observer.

Magnocellular and parvocellular aport contribution for selective and sustained attention

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The objective of this project is to evaluate selective and sustained attention measuring motion coherence threshold considering functional differences from parvocellular and magnocellular pathways' responses to stimuli in movement and frequency for input in visual attention. We developed two tasks in which we prioritized parvocellular (High Spatial Frequency - HSF) and magnocellular characteristics (Low Spatial Frequency - LSF). The stimulus consists a 100 radial sinusoidal grating in a Gaussian envelope of 3 sizes: 10cpd, 5cpd e 0.5cpd, which could dislocate in 2º/s and 10º/s. In order to analyze magnocellular input, we made the measurement of coherent motion for the 0.5cpd stimuli, the others stimuli were distracters. For parvocellular input, the preferential stimuli are 10cpd. Our hypothesis was those coherent motion thresholds would be low for magnocellular inputs, making it easier to allocate attention in a sustained way, while thresholds from parvocellular stimuli would be bigger for stimuli of 10º/s. We evaluated 25 volunteers aged 19-24 years (M=21.67; SD=1.47; 13 females) with normal or corrected-to-normal vision, with no ophthalmologic diseases, and recruited among university students. The average coherence motion threshold for LSF, was 2º/s (M= 11.46; SD= 3.68); 10º/s (M= 12.03; SD= 4.13). For HSF, 2º/s (M= 11.11; SD= 3.80); 10º/s (M= 14.31 com SD= 5.19). We found a significant difference between LSF and HSF for 10º/s (t= 2.28; p= 0.031). Since our results confirm our hypothesis, we can conclude that the method developed is sensible for assessing the psychophysical function from magnocellular and parvocellular contribution in sustained and selective attention. Another contribution of this work is the insertion of perceptual selectivity, considering that the measurement from coherent motion occurs under noise.

Perceived speed in the upper and lower visual fields

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Gibson's ecological theory suggests that optic flow in the lower visual field (LVF) provides more information for locomotion from the ground. In support of this, optic flow presented in LVF leads to larger vection and postural sway compared to the upper visual field (UVF). However, the extent to which visual motion perception itself differs between these fields is unclear,

especially at the suprathreshold level of optic flow. Previous studies have not shown clear evidence regarding differences in perceived speed between the LVF and UVF, but only a relatively small range of eccentricity was tested. To investigate this further, we conducted a psychophysical experiment to match perceived speed in both fields, covering up to 16.5 degrees of eccentricity. Participants were presented with moving random dots for 0.5 s within circular apertures above and below a fixation mark, with dot size, field size, and speed scaled linearly with eccentricity. Participants judged which field contained faster motion, and the speed ratio that yielded subjective equality was obtained by the interleaved staircase method. The results did not show consistent overall bias in either field, but indicated a tendency of more relative LVF bias in further periphery, which was slightly more pronounced for the centrifugal configuration (expansion) that is related to forward self motion. While our results did not directly support a link between perceived speed and the LVF superiority in vection and postural control, they suggest potential qualitative differences in speed coding between the LVF and UVF.

Supported by JSPS Grants-in-aid for Scientific Research (19K03367)

Perception of dynamic stimuli: Toward a new methodology for scotoma patients

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Scotoma is an area of partial or complete alteration of the visual field, encircled by preserved visual capabilities. Previous research has shown that as the brain undergoes plastic changes for compensation, the surrounding visual input appears to be compressed towards the center of the scotoma and the surrounding visual space is remapped. Nonetheless, this remapping has been documented using static stimuli, while in natural scenes we often need to compute dynamic percepts. Further research is thus needed involving the interaction of ecological stimuli and scotoma. Here, we develop a new methodology to study perception within the scotoma with dynamic stimuli. We asked participants to estimate the 3 spatial positions (±6, 8, 10 deg), 3 time durations (500, 1000, 1500 ms), and 3 speeds (2, 4, 6 deg s−1) of visual stimuli considering center and periphery. Such design was needed to directly investigate whether the remapping and reorganization of ecological stimuli involved mainly temporal or spatial representations or if it arose from any combination of the two. The position task was to estimate the location of the target and the duration task was to replicate the duration of the target appearing in different locations. The speed task was to reproduce the trajectory of a target traversing through the scotoma. Our preliminary results showed that sighted participants were precise in estimating temporal duration among the different spatial positions and spatial localization. Bias was observed in speed and position estimation. Considering the previous research, the results suggest that this is a good methodology to follow. Future research will provide a further understanding of whether spatio-temporal representations are distorted in vision and audition as a function of the scotoma's position, underlying the potential role of remapping mechanisms occurring at the cortical level due to plastic reorganization.

Bouncing ball tracking under different background settings can disentangle local and global motion processing

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Visual sensitivity to movement in scenes is served by a hierarchical cortical system with local detectors working together in parallel with global mechanisms. The latter combine information over wider scales than the detectors. In this work, we probed the visual motion system using smooth-pursuit eye movements as a continuous proxy of dynamic cortical processing. Our aim was to uncouple local and global contributions to the dynamic response. We used a bouncing ball task where participants were asked to follow a ball as well as they could during trials of 1s. All generally improved tracking performance during the trial reaching a peak by about 400ms. We manipulated the use of a learned gravity prior with an easy downward and harder upwards or inverted gravity condition. We concurrently manipulated the background making it either plain grey or adding spatiotemporal luminance noise of a range of scales from fine to coarse. The added noise could therefore disrupt local motion detection or non-local processes like representations. We found that background noise of a central frequency within an octave of the size of the ball had the most disruptive effect on tracking. This disruptive noise seemed to introduce subtle oscillations which emerged early under gravity and inverted gravity conditions. Noise at larger, or much smaller scales than the ball led to poorer tracking than the no noise condition, but this disruption did not have the same dynamic characteristics. We unpack these results exploring the possibility that the time-course of the emergence of noise driven disruption can serve as means of disentangling local and global processes. Further, under the inverted gravity condition where tracking was initiated much slower than under gravity, disruptive effects are larger. We discuss whether these results support the notion that gravity tracking is automatic and pre-attentive.

High-speed motion informs object correspondence in the quartet motion paradigm

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Maintaining object correspondence across saccades is challenging because objects rapidly shift on the retina as the eyes move. Here, we use a two-frame quartet-motion display to investigate whether motion at speeds routinely imposed by saccades can support object correspondence. Specifically, we explored how the visibility of motion varies across different speeds during fixation and assessed its impact on the perception of object correspondence. Two identical objects (Gabors) appeared in opposite corners of an imaginary rectangle. One object moved continuously at a constant speed to its new location, either horizontally or vertically and in a curved path. The other object jumped simultaneously to the remaining corner, completing the quartet. The motion's speed either matched the peak velocity of saccades of corresponding amplitudes or deviated from it by six different factors (0.2 to 0.8). Participants reported the perceived rotation of the quartet (clockwise or counterclockwise) via button press (providing a measure of perceived object correspondence) and drew the perceived, continuous motion trajectory using a mouse (providing measures of motion visibility). We measured accuracy in reports for location, curvature, and direction of the drawn trajectories. We also varied the quartet's aspect ratio to measure the effect on continuous-motion visibility on the proximity bias, that is, the preferred perception of the shortest of the two possible paths. We found that the continuous motion's visibility dropped with increasing speed, such that accuracy for location and curvature reports reached chance level. Accuracy for direction reports remained above chance level for even the highest speeds and coincided almost perfectly with rotation reports. Importantly, the continuous motion biased the perceived rotation of the quartet, countering the proximity bias, even at speeds that rendered the location and curvature of the motion invisible. These results suggest that high-speed motion information informs object correspondence, even if that motion is effectively invisible.

Supported by European Research Council (grant No 865715) and Deutsche Forschungsgemeinschaft (grants RO 3579/8-1 and RO 3579/12-1) granted to MR.

The role of Frontal Eye Field pursuit generation in the perception of depth from motion parallax

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The quick, effortless perception visuospatial relations derived from observer self-motion is crucial for successful navigation through a cluttered environment. For the unambiguous perception of depth from motion parallax (MP) the visual system relies on the neural integration of a pursuit eye movement signal, generated to maintain stable fixation during movement, with the simultaneous retinal image motion of stationary objects at distance from the fixation point. To investigate underlying neural mechanisms, Transcranial Magnetic Stimulation (TMS) was used to disrupt the pursuit signal generated by the slow eye-movement region of the Frontal Eye Fields (FEFsem). If FEFsem provides the necessary pursuit signal for perception of depth from MP, and if TMS of FEFsem increases pursuit latency for contralateral movements, then TMS of FEFsem should increase the presentation duration needed for the perception of depth for a MP stimulus translating contralaterally. FEF was localized to individual anatomy (T1-weighted MRI) and functionally refined as the region that produced an increase in pursuit latency when stimulated. TMS was applied to right FEFsem during: i) pursuit, ii) motion perception, and iii) MP depth perception tasks. Eye position was monitored with remote optics eye-tracking. In the MP task, observers reported perceived depth phase (2AFC) upon viewing a computer-generated random-dot MP stimulus making a single translation of duration t, which varied in two interleaved staircases, one for each direction of stimulus translation. TMS produced an increase in pursuit latency in the contralateral direction, but not in the ipsilateral direction. TMS also produced direction and task-specific effects on performance; there was an increase in the MP presentation duration required for depth perception with stimulus translations in the contralateral direction. The temporal magnitude of the pursuit and MP effects were significantly correlated. FEFsem appears to generate the pursuit signal needed for the unambiguous perception of depth from MP.

Acknowledgement: Supported by NIH NEI R15EY031129

Neural representations of observed interpersonal and person-object motion synchrony in the social perception network

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A network of regions in occipitotemporal cortex is known to support the visual processing of individual faces, bodies, and actions. To date, however, relatively little is known about the visual processing of interactions between people. In the present study we sought to contribute to this emerging literature by elucidating the neural representation of interpersonal synchrony. The presence of interpersonal synchrony is a critical cue when appraising the nature and content of social interactions viewed from third-person perspectives. Dyads moving in synchrony are more likely to be perceived as a social unit than those moving asynchronously, and synchrony affords attributions of rapport and affiliation. Initial findings obtained with multi-voxel pattern analysis (MVPA) suggest that the distributed responses seen in extrastriate body area (EBA) and posterior superior temporal sulcus (pSTS) support above-chance classification of synchronous vs. asynchronous head movements. However, it is unclear whether above-chance decoding in EBA and pSTS reflects the representation of interpersonal synchrony per se, or domain-general visual processing of synchronous motion. In a well-powered fMRI study (N = 38), we used MVPA to compare the neural representation of person-person synchrony and person-object synchrony. In the person-person condition, participants viewed two actors, shown face-to-face, shaking their heads synchronously or asynchronously. In the person-object condition, participants viewed a human actor shaking their head while facing a desk fan oscillating synchronously or asynchronously. We were able to train a classifier to decode synchronous vs. asynchronous motion from the patterns of activity seen in various areas of the social perception network, including EBA and pSTS, in both the person-person and person-object conditions. However, certain regions showed superior decoding in the person-person condition, notably left EBA. These results provide important new insights into recent debates surrounding the existence of dedicated neural substrates for the visual processing of social interactions.

Influence of visual patterns and optical flow on inverted pendulum balancing tasks

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Human-made environments can be full of straight-lined, repetitive patterns that induce optical flow when walking or driving past. Some patterns can even disturb human motor control and affect motor stability. We investigated how patterns and optical flow in the background influence stability in two simulated inverted pendulum balancing tasks. This is a simplified first step towards investigating the relation between patterns in modern architecture and human balance disturbances.

In our experiment, participants had to stabilise two simulated versions of an inverted pendulum using a stylus on a graphics tablet while different patterns with sinusoidal movements were applied to the background. One pendulum rested on a joint (a system similar to body balance) and one on a cart (similar to balancing a stick on the hand). In different trials the background patterns were vertical black-and-white stripes, randomly placed dots with random shades of grey, or a plain grey control background. The textured patterns were either static or moving sinusoidally at 0.5 Hz with either low or high amplitude. Sinusoidal movements were chosen to mimic the lateral optical flow induced by human gait.

Our results showed improved balancing performance for static textures compared to the control background, particularly so for the striped pattern that provided a fine-grained orientation reference. Optical flow in the background caused a decrease in balancing performance that was larger for stronger movements in both textured patterns. Performance deteriorated more for dense vertical stripes than for random dots.

Our findings indicate that the nature of a pattern and its movement strongly influence human balancing capabilities. In future studies we will investigate the influence on human postural sway directly, break down the influence of speed of the optical flow, and look into relevant features of common patterns in architecture.

Reading acceleration training combined with multi-session parietal tACS enhances working memory and magnocellular-dorsal stream functionality in dyslexia

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Transcranial Alternating Current Stimulation (tACS) is a brain stimulation method which allows the manipulation of ongoing brain oscillations in a non-invasive way. To date, only few studies have investigated the cumulative effects of multi-session tACS in clinical populations with visual deficits. A growing body of evidence has linked visual impairments in developmental dyslexia (DD) to the disruption of the magnocellular-dorsal (M-D) stream, responsible for the spatiotemporal analysis of visual input. In this randomized, sham-controlled trial we aimed to investigate the efficacy of multi-session beta-band tACS coupled with a visuo-attentional reading training on reading speed, working memory, and neural functionality of the M-D stream.

To this aim, two groups of participants with DD underwent 12 sessions of a reading acceleration training while receiving 18-Hz bilateral-parietal tACS (tACS-Group) or a placebo stimulation (Sham-Group). Before and after the training, participants underwent a digit span evaluation to test the effects of parietal tACS on working memory. Moreover, EEG data were recorded during a coherent motion task to investigate the effects of stimulation on M-D stream functionality. Results showed that both groups significantly improved their reading speed across the training sessions, with greater gain for the tACS-Group. Moreover, the tACS-Group performed significantly better in post-training working memory assessments as compared to the Sham-Group. When looking at the N200-ERP component elicited during coherent motion processing, only the tACS-Group showed a significant increase in amplitude after the training. Given that this component was previously found to be attenuated in dyslexics, this last result can be interpreted as evidence that our stimulation protocol effectively improved the M-D stream functionality. These preliminary findings show that M-D impairments can be targeted by tACS and that combining visuo-attentional reading training with 18-Hz tACS results in synergistic advantages for ameliorating visual processing in DD, possibly through a normalization of beta oscillatory dynamics.

Task/Paradigm influence on CFS performance

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Continuous Flash Suppression (CFS) is a popular tool in the study of visual processing in the absence of conscious awareness. Most studies employ paradigms similar to the original by Tsuchiya and Koch. Previously we demonstrated many factors can influence CFS effectiveness, including features specific to the masks (Zhu, Drewes et al. 2016), and interactions between mask and target (Zhu, Gao et al. 2021). Few studies investigated how the type of task influences suppression in CFS.

We compared three CFS paradigm variants. (1) Break-through-CFS (b-CFS) measures the response time to the stimulus without distinction between targets. (2) 2-position-CFS (2p-CFS) presents the stimulus either left or right of the center, the participant responding to the stimulus by indicating the target location. (3) In 2AFC-CFS the stimulus was presented in the center of the visual field, but participants responded to stimulus category in a two alternative forced choice task.

In all three experiments, we used images of faces and houses as targets, with pink noise masks. Faces always had shorter response times than houses (b-CFS: $F(1,15) = 7.404$, $p = 0.016$; 2p-CFS: $F(1,15) = 13.794$, $p = 0.002$; 2afc-CFS: $F(1,15) = 8.709$, $p = 0.010$). b-CFS had the shortest break through time (2046 ms), followed by 2p-CFS (2320 ms) and 2AFC-CFS (2426 ms), $F(2,62) = 10.606$, $p < 0.001$). 2p-CFS vs. 2AFC-CFS was not significant ($p = 0.713$). This tendency showed in face and house stimuli, however with faces the difference between 2p-CFS and 2afc-CFS (21.94 ms) was smaller than with houses (189.31 ms).

We suspect the differences to represent differences in processing. b-CFS is mostly object detection (no discrimination). In 2AFC-CFS, correct responses require object identification, needing more time than b-CFS. 2p-CFS is an intermediate, requiring target location, thus increasing task demand.

Metacognition of perceptual evidence accumulation in the first 50 milliseconds of viewing

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Drift diffusion models have often been used to model reaction times in visual discrimination tasks. Typically, these models use a constant drift rate, which corresponds to the strong assumption that visual information accumulates at a constant rate. More recently, non-stationary drift diffusion models introduced time-dependent drift rates allowing for variability in the speed at which internal evidence accumulates. But these models still are fitted to data obtained from fixed stimulus presentation times making conclusions heavily dependent on model assumptions. We aim to provide more direct empirical access to the variability of drift rates. For this, we exploit a striking similarity in the mathematical formulations between (a) evidence accumulation processes in drift diffusion models and (b) confidence weighted majority voting which is typically used to study group decisions. Each additional time step in a drift diffusion process accumulates evidence in the same way as a group of experts accumulates evidence when an additional expert joins the group. This relationship inspired a simple psychophysical experiment (N = 6, each participant was measured in three two-hour sessions) analyzed with a new perspective: Participants discriminated masked stimuli at different presentation durations and also rated their confidence in this discrimination. Confidence ratings were calibrated and logit-transformed, such that we obtained a proxy for the internally accumulated evidence. Studying how these distributions of accumulated evidence change dependent on the stimulus presentation time allows observing changes in drift rates more directly. Participants in our experiment — despite substantial interindividual differences — reliably show an acceleration in their evidence accumulation throughout the first 50 milliseconds of visual processing. This approach offers a stronger empirical grounding for estimating time-dependent drift rates. We discuss how this approach can complement drift diffusion models as well as potential limitations caused by our use of participants' metacognitive abilities.

Signal detection measures can (!) distinguish perceptual biases from response biases

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A common assumption when looking at visual after effect or other perceptual effects is that these are purely perceptual and will be reflected in changes of d' or correspondingly meta d', when coupled with the awareness of that perceptual change or bias. Against that common assumption, Witt et al. (2015) argued in their paper that Signal detection measures cannot discriminate between perceptual biases, such as a motion aftereffect, and criterion setting, response bias. They propose that an effect on perception may effect measured bias instead of d'. If it effects bias, there would consecutively be no way to discern perceptual bias, for instance to measure the strength of a motion after effect, and response bias, such as internal criterion setting. Hence, we would not be able to tell to what extent a perceptual effect is purely perceptual and not conflated with response bias. Especially when using perceptual bias in psychopathology or perceptual tasks, to discriminate between the two is crucial and can lead to incorrect results when neglected.

We propose a task and modelling approach that dissociates perceptual bias from response bias. Using a motion after effect illusion, we show that measuring the strength of the motion after effect with d' as well as with psychometric functions and models building on psychometric functions, such as Bayesian models, is conflated with responses, hence criterion setting bias, which has never accounted for in previous studies. With a dissociation in the task design, presenting the task as 1-Interval and 2-Interval and b.) by controlling for the additional noise of the two 2-AFC with a SDT vs. a Bayesian modelling approach, we were able to dissociate pure perceptual bias from response bias. We find that circumventing the criterion setting process, and controlling for additional 2-AFC induced noise, strongly and significantly enhances perceptual bias effects.

Transitions during binocular rivalry vary in appearance across stimulus types

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Our subjective experience of the information we receive through the sensory organs is rich and complex. Yet, typical cognitive psychology paradigms reduce it to a few pre-defined discrete categories (yes/no answers, 5-point Likert scales, etc.). In the current study, we examined the complexity of subjective visual experience in a binocular rivalry task, which occurs when the two eyes are presented with two different images that cannot be fused into a uniform percept. As a result, the conscious perception alternates between the two images with brief transition phases in-between. Thirty subjects viewed binocular rivalry produced by pairs of stimuli with different visual information (face, house, grating or moving dots). After each rivalry period, they described their perception during the transitions verbally and as a sketch drawing. To quantify the response consistency of participants this procedure was repeated after several weeks. Then, two independent raters categorized transition types using content analysis. The raters agreed on seventeen different categories (Cohen's kappa: 0.64), which were subsequently used to determine which categories were present in the description of each participant for each visual stimulus combination. On average, participants reported 8 +- 2 unique categories (3 +- 1 for each visual stimulus combination). Participants' responses were consistent across sessions (Sorensen-Dice coefficient: 0.85 +- 0.6). Six of the 17 categories were significantly affected by stimulus content (i.e., being present for static images but not moving dots and vice versa). Our results show that perceptual transitions during binocular rivalry appear in different forms, and depend on the specific visual stimulus type that induces binocular rivalry. These findings have implications for neuroimaging studies of binocular rivalry, which may lead to different results depending on the exact experience of transitions. They also demonstrate how the complexity of subjective visual experience may be underestimated in traditional perception paradigms.

Disentangling the contribution of conscious and unconscious processes to breaking continuous flash suppression

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The so-called breaking-Continuous Flash Suppression (bCFS) paradigm measures the time it takes stimuli initially suppressed from awareness through strong interocular suppression to be detected. BCFS has been widely used to study which stimuli are prioritized by the visual system for access to awareness. However, it remains debated whether differences in detection times during bCFS reflect differences in unconscious or conscious processing. To address this question, here we measured access to awareness during standard bCFS, where an initially invisible target presented to one eye eventually overcomes interocular

suppression induced by masks presented to the other eye that are progressively ramped down in contrast, and in a novel "reverse" bCFS paradigm, where an initially visible target presented to one eye is eventually suppressed from awareness by progressively increasing the contrast of masks presented to the other eye. This reverse-bCFS condition should capture conscious prioritization and, thus, by comparing standard with reverse bCFS the relative contribution of unconscious vs. conscious processes to detection differences may be isolated. Testing the well-established difference in detection times for upright vs. inverted face stimuli, we found faster detection of upright faces in bCFS ($p < .01$) and slower disappearance of upright faces in reverse-bCFS ($p < .05$). Comparisons of standardized face-inversion effect indices from standard- and reverse-bCFS revealed that the FIE was greater in standard bCFS ($p < .05$). This suggests an important contribution of unconscious processes in prioritization of upright faces for awareness that is independent of the influence of conscious processes (e.g., top-down attention) on the face-inversion effect. More generally, we propose that the combination of the standard- and reverse-bCFS will offer a straightforward approach to disentangle the effect of conscious and unconscious processes on detection effects under interocular suppression, and may thus represent a novel tool in the study of visual awareness.

Masking by four dots revisited: The role of mask related attention

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When four small dots arranged in a notional square follow a target stimulus after a short interstimulus interval the processing of the target stimulus is severely reduced. This 4-dot masking effect can be distinguished from other types of masking because of the low intensity of the four dots and the significant distance between the dots and the target stimulus. While unfocused spatial attention can exacerbate masking in general, for 4-dot masking, this has been suggested as a key factor, based on finding masking to be absent for a single target or when a pre-cue singled out the target prior to the presentation of the mask. Reducing the number of objects carrying the target feature instead of reducing the number of objects in general, we rule out source confusion as an alternative explanation. Although possibly reduced compared to previous studies, where the mask needed to be actively attended to identify the target, we still observe substantial masking effects, in a paradigm where the mask can virtually be ignored. Based on this we tested, whether mask manipulations expected to alter attention modulate masking strength. No increase of masking was observed, when a second mask (intended to broaden attentional spread) was added in locations vis-à-vis to the target. Two further approaches directly modulating mask-salience did not yield an increase either: Masking was similar irrespective of whether mask and target had opposite or same polarity contrast; adding movement to the mask, rather than an expected increase, a slight decrease in masking strength was observed. While these findings indicate that attention to the mask, does not play a major role in 4-dot masking, the lack of polarity effects provides new evidence for the distinguished nature of this type of masking.

Perception, Concept, Language - A new Approach to Connect Philosophy of Mind and Empirical Science

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Visual perception is a research topic of both, philosophy and empirical science. However, the two disciplines are not adequately intertwined. In our project, we use empirical research on emotional expressions of faces as an example to show that an interaction of both fields can be beneficial.

The ability to recognize emotions on faces (e.g., happiness, sadness, anger) seems to be much easier than the ability to name the specific facial features by which the respective emotion was recognized (e.g., wrinkles of the forehead, corners of the eyes, facial muscles etc.). Both abilities are fundamentally dissimilar.

On closer analysis, this difference between recognition and linguistic designation is not accidental. Instead, it points to the systematic question of whether visual perception is conceptually structured and can be translated into language. We argue that a philosophical distinction between concept and language can help to explain the mentioned dissimilarity. In modern philosophy of mind, perception is described as either "conceptual and linguistic" (conceptualism) or as "non-conceptual and non-linguistic" (non-conceptualism). Contrary to this, we support the hypothesis that perception of facial emotions is a good example of a conceptual but not (or not necessarily) linguistic form of perception.

Following Schröder's and Demmerling's (2013) definition of concept, we propose to define concepts as active skills for classification that, as practical actions, do not require language. This definition makes it easier to understand why we lack description or translation of perceptual content – especially content of the "visual recognition type" – and gives an explanation from a philosophical perspective. Furthermore, the definition prompts us to search for new study designs in empirical research that are not trying to translate the contents of perception into language but focus on non-verbal forms of research tasks.

Successor representations of subliminal dots

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Previous fMRI research has shown that when human observers are shown a sequence of dots moving in a predictable way, successor representations emerge in the brain. These successor representations code for the upcoming events, in line with theories on predictive coding. We used a backwards masking procedure to present participants with a sequence of subliminal (i.e. not consciously visible) dots. The dots in the sequence followed a clockwise or counter-clockwise direction, such that every dot predicted the location of the next dot in a straightforward way. Crucially, every sequence (4-8 dots) ended with a probe detection task where a supraliminal (i.e. consciously visible) probe was offset at one of the eight dot locations. The probe location could either be the last location in the dot sequence, the prior location, or the upcoming location. We observed a reaction time benefit for the upcoming location relative to the prior location, which we take as evidence for a successor representation of subliminal stimuli. In a separate phase, we confirmed that the dots were not consciously perceptible.

Fair Masking Eliminates the Face Advantage in CFS

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Continuous Flash Suppression (CFS) is a highly popular method, commonly used for the study of visual processing in the absence of visual awareness. Differences in stimulus break-through time are generally considered as evidence for differential processing of stimuli before reaching conscious awareness. However, interactions between stimuli and masks may lead to substantial differences in break-through time (Zhu, Witzel & Drewes 2022).

Pictures of faces are thought to break through CFS faster than other stimuli (e.g. houses), however the masking in previous studies was generally not controlled for mask/stimulus interactions. Here, we generate target-specific masks that are intended to induce fair masking, without bias against either of the target categories. Starting from white noise images, we apply the amplitude spectrum of the individual target to the noise images, resulting in a series of masks adapted individually to the specific target image. The degree of similarity of spatial frequency and orientation between masks and targets should therefore be equal for all targets, and thus fair.

43 participants successfully performed the experiment. Of these, 35 exhibited the trend that faces broke CFS faster than houses under Mondrian masking, resulting in a significant face advantage under Mondrian masking (df=68, t=2.78, p=0.007). As expected face inversion eliminated the face advantage (df=68, t=1.31, p=0.196). However, with the masks designed individually for each target, the face advantage was eliminated also in the upright condition (df=68, t=0.7, p=0.486).

If break-through time is indeed an indication of unaware processing, it appears this processing was suppressed by fair masking; possibly however we simply avoided a specific masking bias. (Un-)intentional interactions between masks and targets can both induce and suppress strong effects, which may then erroneously be interpreted as differences in unaware processing of visual stimuli. Care should be taken to select suitable masks in CFS-based studies to avoid biased results.

Short-term Neural Changes during Learning of Visual-Manual Gestures: An fMRI and DTI Study

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Visual-manual gestures, such as those used in signed languages, rely on vision-based communication through facial expressions with hand shapes and movements. Neuroimaging studies show that signed and spoken languages activate similar areas of the brain in the frontal and parietal regions, but the specific roles of these areas and how early they get involved remain unclear. In this study, we investigate the impact of short-term training-related changes in learners of British Sign Language (BSL). We conducted pre- and post-training Functional Magnetic Resonance Imaging (fMRI) and Diffusion Tensor Imaging (DTI) scans on twenty-six right-handed healthy volunteers who were taught to discriminate and sign basic sentences using BSL for three consecutive days (one hour per day).

Our results show that short-term training led to increased brain activity in multiple cerebellar and brain areas associated with language, memory, and visual processing. We also observed significant functional connectivity changes between these areas, including the visual occipital network and the visual medial network. Furthermore, our DTI findings revealed significant mean diffusivity (MD) and radial diffusivity (RD) reductions in the left angular gyrus, which were significantly correlated with behavioural improvement. These rapid microstructural changes identify the left angular gyrus as a structure that rapidly adapts to newly learnt visual-semantic associations. These results

suggest a high degree of similarity in the neural activity underlying signed and spoken languages.

In conclusion, our study provides insights into the short-term neural changes that occur during the learning of visual-manual gestures. These findings have implications for our understanding of language learning and the neural adaptations that occur during the acquisition of sign language.

Alpha-band audiovisual entrainment improves audiovisual temporal acuity

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Visual and auditory stimuli are transmitted from the environment to sensory systems with different timing, requiring the brain to encode when sensory inputs must be bound into a coherent percept. The probability that different audiovisual (AV) stimuli are integrated into a single percept even when presented asynchronously is reflected in the construct of temporal binding window (TBW), an index of the probability that two stimuli are integrated into a single percept across a range of stimulus onset asynchronies (SOAs). Interestingly, recent evidence suggested that alpha brain oscillations could represent the temporal unit of AV perception, testing the possibility to broaden or shrink AV TBW, and thus improving AV temporal acuity, speeding up or slowing down the ongoing alpha oscillations by using transcranial Alternating Current Stimulation (tACS). Here, we employed a web-based AV sensory entrainment paradigm combined with a Simultaneity Judgment task using simple flash-beep stimuli. The aim was to probe whether AV TBW could be modulated trial-by-trial by synchronizing ongoing neural oscillations in the pre-stimulus period to a rhythmic AV stream presented in the upper (~12 Hz) or lower (~8.5 Hz) boundaries of the alpha band. As a control, we employed a non-rhythmic condition where only the first and the last entrainers were presented. In half of the trials, the visual stimulus followed the audio stimulus in the auditory leading (AL) condition, and vice versa for the visual leading (VL) condition. Results revealed that upper alpha stimulation shrinks AV TBW, improving AV temporal acuity, with respect to lower alpha and control conditions, modulating both AL and VL conditions. Our findings represent a proof-of-concept of the efficacy of AV entrainment to functionally modulate AV temporal acuity in a trial-by-trial manner, provide new insights for expanding the notion that alpha oscillations could reflect the temporal unit of AV temporal binding mechanisms.

Context-dependency mechanisms in auditory distance estimation: the effect of blindness.

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Often what we perceive does not precisely match the information we receive from our senses but may be influenced by prior knowledge. An example is the phenomenon of central tendency, whereby estimates of specific values, such as distance, duration, or numerosity, tend to converge towards the average of the absolute values. Nevertheless, this mechanism may be modified in populations where perceptual information is distorted due to the absence of a sensory modality, such as blindness.

To tackle this point, we asked a group of blind people, congenital and late, and a group of controls, to perform an acoustic distance reproduction task, in which the stimulus lengths come from different distributions defining two sets of short and long distances. Participants listened to two consecutively presented sounds separated by one of five distances for each set of stimuli (short and long). Once the second sound was localized, participants reproduced the perceived distance starting from that position.

We found a difference between sighted and blind participants in distance reproduction estimates for short and long distances. While the controls and the late blind group show a clear regression toward the mean, the congenitally blind do not. Moreover, the relative importance of the current sensory signal and priors differs among groups. These results suggest that vision may play a role in constructing priors devoted to the distance estimation of sounds.

Funded by EU H2020 ERC g.a. No 948349 - MYSpace, No 804388 – wHiSPER, EU MSCA-2021-PF-01 g.a. No 101064748 - FLEX-U

Testing a Bayesian model of perceived visual and auditory speed during self-controlled head rotation

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Most Bayesian models assume that sensory signals are unbiased. Perceptual inference is therefore determined by internal prior expectations whose influence is weighted by the precision

of sensory inputs. For motion, a slow-motion prior would thus predict that objects should appear slower as sensory precision decreases. This could explain why self-motion appears slower than image-motion, if the precision of self-movement signals is lower. Experiment 1 tested this hypothesis by investigating perceived speed of moving stimuli that were viewed or listened to with and without head rotation. In half of the conditions, noise was added to stimuli in the form of a size jitter to decrease image-motion precision. In this experiment we used a novel technique to compare the relative bias and precision of head-movement and image-motion signals. Stimulus motion was always a fixed proportion of the recorded real-time head movements. Psychometric functions were used to determine the relative bias and precision of image-motion and head-movement signals, with the fitting procedure designed to account for the external noise introduced by the variation of head movements across trials. Overall, we found that the precision of image-motion signals was either the same or worse than the head-movement signal. However, all conditions produced the same relative bias, specifically a proportional slowing of perceived speed with head rotation. Adding noise decreased the precision of image-motion signals but didn't affect relative bias. In Experiment 2, we generalised these findings by training participants to turn their heads at different speeds (20, 50, 80, 110, 140 deg/s). Using auditory stimuli only, we found the same proportional change in perceived speed regardless of the mean speed of head movements, with the image-motion signal consistently less precise than the head-movement signal. These results are difficult to explain in Bayesian terms even if the assumption of unbiased sensory signals is relaxed.

Examining the automaticity of sound–shape correspondences

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Classic examples of sound–shape correspondences are the mappings between the vowel /i/ with angular patterns and the vowel /u/ with rounded patterns. Such crossmodal correspondences have been reliably reported when being tested in explicit matching tasks. Nevertheless, it remains unclear whether such sound–shape correspondences automatically occur and modulate people's perception. Here we address this question by adopting the explicit matching tasks and two implicit tasks. In Experiment 1, we examined the sound–shape correspondences using the implicit association test (IAT) where the sounds and shapes were both task-relevant, followed by the explicit matching tasks. In Experiments 2 and 3, we adopted the speeded classification task; when the target was a sound (or shape), a task-irrelevant shape (or sound), either being congruent or incongruent to the target, was simultaneously presented. In addition, the explicit matching tasks were performed either before or after the speeded classification task. The congruency effect was more pronounced in the IAT than in the speeded classification task; in addition, the auditory congruency effect in the speeded classification task occurred only when following rather than preceding the explicit matching tasks. Lastly, a bin analysis of RTs demonstrate that the congruency effect was observed in the later time bins rather than in the first. Given that the congruency effects were susceptible to the attention allocation and the order of implicit and explicit tasks, and that they occurred at later responses, we suggest that the associations between sounds and shapes were not automatically encoded.

tCFS: A new 'CFS tracking' paradigm reveals uniform suppression depth regardless of target complexity or salience

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When the eyes view separate, incompatible images, the brain suppresses one image and the other is perceived. This interocular suppression can be prolonged by presenting a dynamic stimulus to one eye, resulting in continuous flash suppression (CFS) of the static image. Measuring how long a suppressed image takes to breakthrough CFS (bCFS) is often used to investigate unconscious processing and has led to controversial claims about visual processing without awareness. Advocates interpret faster bCFS times to salient stimuli as evidence for unconscious high-level processing, while opponents claim differences in low- level stimulus features determine breakthrough times. We address this controversy with a new 'CFS tracking' paradigm (tCFS): the initially suppressed image steadily increases in contrast until breaking suppression (indicated by a key press) and then begins decreasing until it again becomes suppressed (indicated by another key press) after which contrast rises

again and the cycle continues. Unlike bCFS, tCFS provides contrast thresholds for breakthrough and suppression, with the threshold difference providing a measure of CFS suppression depth. This new tCFS paradigm confirms that: (i) breakthrough thresholds differ across target type (e.g., grating vs face) – as bCFS has shown – but (ii) suppression depth does not vary across target type. Once breakthrough contrast is reached (which varies over stimulus category, likely explained by low-level stimulus factors), all stimuli show a strikingly uniform reduction in the corresponding suppression threshold and thus a constant suppression depth. Uniform suppression depth indicates a single mechanism of CFS suppression, one likely occurring early in visual processing where it is not modulated by image salience or complexity. Results from this new tCFS method disclose that variations in breakthrough thresholds alone do not suffice for drawing inferences about unconscious

processing – complementary suppression thresholds are required to preclude potentially misleading conclusions.

Modeling Depth Cue Combination

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How does the human visual system combine individual depth cues to form the overall depth map? Empirical data show that it departs from ideal cue combination behavior in various ways which can be used to identify the underlying combination rules that are brought into play. Understanding the combination logic is important for visual ergonomics, such as the optimization of vehicle displays and the design of XR environments. Data for perceived depth from texture show unexpected anisotropies and interactions between disparity and texture cues (Buckley & Frisby, 1993, VR). We model these nonlinear interactions by a hyperbolic compression function limited by binocular texture shape invariance. Thus, perceived depth is fully expressed for disparities carried by differential (horizontal) shifts of local texture elements between the two eye's views, but is suppressed for disparities requiring density compression of the texture-element shapes across the display. This 2D shape invariance constraint is a third principle operating in depth estimation, distinct from the logic of the depth-from-texture-density cue. The resulting suppression is released under monocular viewing conditions, however. A mathematical model implementing these three principles provides a satisfactory fit to the empirical data for perceived depth in displays combining disparity and texture cues under both binocular viewing conditions, to account for the monocular behavior by a release from the shape-distortion constraint. Such a cue suppression model does not conform to a weighted linear summation principle, or a Bayesian cue combination model where the weights are inversely proportional to the variance of each cue.

Alpha rhythms support coherent natural vision through feedback to early visual cortex

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To create coherent visual experiences, the brain must spatially integrate the complex and dynamic information it receives from the environment. The visual system achieves this by utilizing contextual information from one part of the visual field to generate feedback signals that guide analysis in other parts of the visual field. Here, we set out to investigate the nature of this feedback across brain rhythms and cortical regions. In the first study using both EEG and fMRI, we mimicked the spatially distributed nature of visual inputs by presenting natural videos at different locations in the visual field. Critically, we manipulated the spatiotemporal congruency of the videos to either demand or not demand integration into a coherent percept in EEG and fMRI experiments. Our decoding analysis on frequency-specific EEG patterns revealed a shift from representations in feedforward-related gamma activity for spatiotemporally incongruent videos to representations in feedback-related alpha activity for congruent videos. In addition, our fMRI data suggest that high-level scene-selective areas may serve as the putative source of this feedback. By combining frequency-resolved EEG data with spatially resolved fMRI recordings, we found a direct association between alpha-frequency feedback and representations in early visual cortex. In a second EEG study, we further probed the involvement of feedback-related alpha rhythms with stimuli of varying degrees of congruency across the visual field (complete congruency, congruency in basic-level category, congruency in superordinate category, and compete incongruency). Our results suggest that the involvement alpha-frequency feedback is parametrically modulated by spatiotemporal congruency. Together, our results demonstrate that the human brain creates coherent visual experiences by using feedback to integrate information from high-level to early visual cortex through a dedicated rhythmic code in the alpha frequency range.

Pre-stimulus alpha speed dictates the precision of visual perception

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Growing evidence seem to support the hypothesis that perception relies on discrete sensory processing mechanisms. Brain oscillations in the alpha frequency band (7-13 Hz) have been proposed as a neural candidate that could underpin these discrete processes. According to this hypothesis, alpha rhythms would play a role in segmenting visual input into temporal units by setting the pace of sensory processing, with faster alpha oscillations translating into higher temporal resolution and more accurate perceptual experience.

Here, we investigated this hypothesis by assessing whether trial-by-trial fluctuations in pre-stimulus alpha frequency account for the accuracy of visual contrast detection in a large sample of individuals within the general population (n = 120). We employed an advanced data analysis method to investigate our hypothesis, controlling for perceptual bias, by using both state-of-the-art computational models applied to visual perception (signal detection theory, drift diffusion model) and robust statistical tests (Bayesian statistics and nonparametric analysis).

Results show that the variability in alpha speed aids in explaining inter-trials differences in perceptual performance. Notably, trials in which alpha pace is faster were associated with 1) higher mean accuracy, 2) higher sensitivity (i.e., higher d' but not criterion) and 3) higher drift rate parameter (but not starting point).

These findings provide novel strong evidence, in support of the hypothesis that alpha frequency serves a sampling mechanism able to shape visual performance, in which higher frequencies promote greater temporal resolution, through the sampling of more visual frames per time unit.

The faster the better: alpha peak frequency is related to general visual performance

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Alpha waves (8-13 Hz) are one of the dominant rhythms of brain activity. Previous findings suggest a link between alpha activity, neural excitability, and perception, with faster individual alpha peak frequency (IAPF) implying finer temporal resolution. In this study, we examined the relationship between IAPF and visual performance in a large sample of healthy controls and patients with schizophrenia. Participants were presented with a vernier alone, a vernier followed by a mask at two different SOAs (30 and 150ms), or only a mask. In all conditions, participants were asked to discriminate the vernier offset (left vs. right). IAPF was estimated at rest without stimuli shown. We tested two hypotheses: 1) if IAPF determines temporal resolution, it should correlate with performance only in the 30ms SOA condition because this is the only condition where time matters, i.e., where vernier and mask can fall within the same alpha cycle; 2) if IAPF reflects a more general aspect of processing, such as increased attention, its association with performance should be evident in all conditions presenting a vernier. In line with previous studies, our results confirm a slower IAPF in patients with schizophrenia, and we found a significant association between IAPF and visual performance in both groups. Importantly, this association was present in all conditions. Together, our findings therefore suggest that IAPF reflects a general aspect of processing rather than a specific function in temporal integration.

Predicting Binocular Rivalry Individual Differences from Resting MEG Aperiodic Alpha

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Binocular rivalry (BR) 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. This fascinating dynamic visual illusion has been studied extensively as a window on to creative visual perception and conscious awareness. It is also known that individual subjects experience perceptual alternations at different rates, and this a stable, heritable trait. Interestingly, there are indications that even at rest, alpha brain activity may predict rivalry dynamics in behavioral testing. Specifically, the peak frequency of alpha oscillation predicts individual differences in the alternation rate of BR (Katyal et al., 2019); the highest alpha was found in the bilateral parieto-occipital EEG electrodes. In this study, we recorded subject's perceptual reports (N = 48) while viewing rivalry with orthogonal gratings (red in one eye and green in the other). We examined MEG resting state data (5 min, fixation point only) from the parieto-occipital cortex using MRI-assisted source localization with Brainstorm software. In addition to seeking replication, we aimed to examine this potential brain-behavior correlation with new methods developed by Donoghue at al., 2020 for parameterizing the alpha band neural power spectra into periodic and aperiodic components. With the benefit of these new methods, we found that the expected interaction between the periodic peak alpha frequency at rest and duration of dominant BR percepts was not statistically significant. In contrast, we did find a significant correlation between duration of dominant BR percepts and the aperiodic component (estimated by the exponent fit). Interestingly, the exponent is thought to represent the balance of excitation and inhibition (E:I). The current results converge with new evidence that the aperiodic (1/f-like) component of neural activity is physiologically distinct, and may underpin a range of behavioral states in normal and abnormal cognition.

Contextual modulation of laminar BOLD profiles in V1

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In primary visual cortex (V1), both long-range lateral connectivity and feedback from higher order visual areas contribute to shaping neural responses based on spatial context. However, it is unclear exactly how and to what extent lateral and feedback connectivity individually contribute to contextual modulation of neural responses in V1. Developments in ultra-high-field functional magnetic resonance imaging (fMRI) have enabled non-invasive imaging of cortical lamina in humans, which can be exploited to examine the cortical origins of neural signals underlying blood-oxygenation-level-dependent (BOLD) contrast. We acquired data from six participants using 7T fMRI at 0.6 mm isotropic resolution to measure the influence of visual context on BOLD response profiles across cortical depth in V1. Participants viewed sine-wave grating disks (2 cycles per degree, 40% contrast, 2-degree diameter at 3 degrees

eccentricity) embedded in 20-degree diameter surround gratings with matched spatial frequency and contrast. Segmentation cues were provided by either an offset in relative orientation or an offset in relative phase between center and surround gratings for a total of three context conditions plus a surround-only condition to measure the effects of cortical feedback in the absence of feedforward input. The context conditions allowed us to isolate the effects of orientation-tuned surround suppression (OTSS), a canonical example of contextual modulation in V1, from non-orientation dependent figure-ground modulation (FGM). We found significant modulation of BOLD signal in center-selective voxels in the absence of feedforward input, suggesting that feedback and recurrent connections can drive strong BOLD responses in V1. Surprisingly, we found only weak signatures of OTSS that were primarily localized to superficial layers. We conclude that a large fraction of the BOLD signal measured in V1 cannot be attributed to feedforward mechanisms and that feedback appears to modulate the BOLD response broadly across cortical depth.

Discrete classes of neural activations for binocular disparity in human visual cortex

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Visual perception of fine depth is strongly dependent on binocular stereopsis, the ability to decode depth from the horizontal offset between the retinal images in the two eyes. Here we used fMRI responses (2mm isotropic) to investigate how tuning for binocular depth is organized across human visual cortex. We employed a time-varying parametric modulation of binocular disparity to characterize the neural tuning for disparity across multiple visual areas. Participants observed a random-dot stereogram stimulus whose disparity varied in depth over time. Cortical responses were modelled using the haemodynamic response function to deliver a 1-dimensional tuning curve for depth at each sample point across the cortical surface. Tuning was visible in the responses at single vertices across the visual cortex. Density-based clustering analysis indicate distinct populations of tuning types, revealing selective tuning for near and far disparities from early visual areas (V1, V2) out to higher visual areas (LOC). Our data reveal the expected relationship between preferred disparity and tuning curve width, with sharply tuned disparity responses at near-zero disparities, and wider disparity tuning profiles encoding large near or far disparities. The population tuning density for disparity was also greatest in the zero disparity plane in V1 but was biased towards near disparities in V5, similar to neurophysiological recordings in macaque. Responses to anti-correlated random-dot stereograms were also tuned for stimulus disparity in some cortical areas. In V5 and early areas, responses to anti-correlation showed evidence of sign inversion whereas in higher visual areas responses were sparse and disorganised. These findings point to heterogeneous processing of disparity across human visual areas, suggesting that neurons sensitive to binocular stereopsis play different roles in different visual areas.

Perceptography: unveiling visual perceptual hallucinations induced by optogenetic stimulation of the inferior temporal cortex.

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Artificial perturbation of neural activity in the inferior temporal (IT) cortex, the high-level visual area associated with object recognition, alters visual perception. Quantitative characterization of these perceptual alterations holds the key to developing a mechanistic theory of visual perception. Nevertheless, the complexity of such stimulation-induced hallucinations in the context of their subjective nature has historically rendered the problem hard to crack. In order to crack this problem, in this study, we developed a novel method, perceptography, to "take pictures" of the hallucinations induced by artificial stimulation of IT cortex. We trained macaque monkeys to detect and report 200ms optogenetic impulses delivered to their IT cortex via an implanted LED array. We assumed that the animals perform this task by detecting the stimulation-induced alterations of the contents of their vision. We required the animals to hold fixation on a set of seed images during the task. We then utilized a machine-learning structure to physically perturb the seed images to trick the animals into thinking they were being stimulated. This was achieved by assigning an optimizer to track the animals' behavioral false alarms (nonstimulated trials reported as stimulated) across thousands of random image perturbations. In a high-throughput iterative process of behavioral data collection, the optimizer guided a generative artificial neural network (GAN) to develop highly specific perturbed images, perceptograms, looking at which would trick the animals into feeling cortically stimulated. Specifically, while the baseline false alarms rate was ~3%, perceptograms induced false alarms in 70.1% of trials. We also showed that the magnitude and nature of alterations in the resulting perceptograms highly depend on the location and magnitude of stimulation. Perceptography provides parametric and pictorial evidence of the visual hallucinations induced by cortical stimulation and allows the establishment of theoretical homeomorphism between objective neural states and their equivalent subjective perceptual state.

White matter tracts connecting ventral and dorsal visual streams have distinct microstructural profiles and developmental trajectories

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Visual informationinthehumanbrain is processed along at least two parallel yet interacting streams that change throughout development: the ventral and dorsal streams. The ventral and dorsal streams are connected structurally by the posterior vertical pathway (PVP), a major white matter pathway that can be segmented into at least four tracts: the posterior arcuate (pArc), the middle longitudinal fasciculus connection to the angular gyrus (MDLFang), the temporal-parietal connection to the superior parietal lobe (TPC), and the middle longitudinal fasciculus connection to the superior parietal lobe (MDLFspl). Here, we used diffusion tractography and microstructural modeling to characterize the tissue properties of these four PVP tracts throughout development in a large sample (n=554) ranging in age from 3 to 22 years. We estimated the developmental trajectory for each tract by identifying the age at which the fractional anisotropy (FA) of the tract reached its peak based on a non-linear model (i.e., FA~age^2). Results demonstrated that each tract had a unique FA profile that was consistent throughout the tested age range and did not differ significantly between hemispheres. Age at peak FA varied among the tracts, with the pArc reaching peak FA at 14 years, followed by the MDLFang at 14.5 years, the TPC at 15.5 years, the MDLFspl at 20 years. Age at peak FA varied between hemispheres, with the left hemisphere tracts reaching peak FA values approximately 1-2 years earlier than the right hemisphere homologues. Taken together, results demonstrated that the pArc, MDLFang, TPC, and MDLFspl have unique microstructural profiles and undergo different developmental trajectories, suggesting that segmenting the PVP into these four tracts will yield unique insights into ventral-dorsal interactions in human behavior and throughout development.

Funding Acknowledgements:

Franco Pestilli: NSF (OAC-1916518/IIS-1912270/IIS-1636893/BCS-1734853), NIH (NIMH R01MH126699, NIBIB R01EB030896/R01EB029272), Wellcome Trust (226486/Z/22/Z), Microsoft Investigator Fellowship, Kavli Foundation. Zoha Arif: SyBURRE Searle Undergraduate Research Program.

Feature selective adaptation of numerosity perception

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Numerosity perception refers to the ability to make approximate but reliable estimates of the number of items in a set. Alike many other primary visual features, numerosity perception can be prone to distortions via sensory adaptation, inducing robust under- or over-estimation (30%) of numerosities following adaptation to high and low numerosities respectively. Previous studies showed that numerosity perception can be quite abstract, prescinding stimuli format and modality. However, a recent study found that numerosity adaptation is selective to item color similarity between adapting and testing stimuli, with aftereffects occurring only for items matching the adapted hue. Here, we tested whether this selectivity of numerosity adaptation generalizes to other salient visual features. Participants performed a numerosity discrimination task on simultaneously presented visual arrays (N=12-48 dots) before and after adaptation to 48 dots. In four different experiments we evaluated the presence of selective adaptation aftereffects when adapting and testing stimuli were matched for color (same vs different color), motion profile (translational moving vs still dots), shape (circles vs non-circular shapes with matched energy) and letter type (letter b vs p, d, q and B letters). Occasionally, participants were also asked to report individual stimulus' identity to ensure this dimension was attended. The results replicated previous findings showing color-selective numerosity adaptation. However, despite participants attended to stimuli identity (~ 90% of correct responses), numerosity adaptation transcended the similarity between adapting and testing stimuli and provided robust aftereffects regardless stimuli showing identical or different characteristics. These results indicate that, despite numerosity adaptation aftereffects are selectively tuned to color, such selectivity might not generalize to all salient environmental features, suggesting a key role of color in objects' segregation and processing of quantities.

The symmetry-induced numerosity underestimation is attention-dependent

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While symmetry is one of the strongest cues, we rely on to segment objects in a visual scene, it can sometimes bias our perception. The number of segmented objects can be underestimated if they are arranged symmetrically compared to when they are randomly scattered in space. The reason for this underestimation is currently unknown. Here we investigated whether this bias is related to the intrinsic perceptual grouping

of symmetrical items. Previous studies observed numerosity underestimation when grouping is made explicit by lines connecting pairs of items and demonstrated that this illusion is attention dependent. If the symmetry-induced numerosity underestimation also depends on grouping strategies, we expect it to require visual attention as well. We asked twenty-six adults to judge the numerosity of arrays of dots arranged symmetrically or randomly in space, while ignoring (single task) or while simultaneously performing a color conjunction task on a visual stimulus (dual task). The numerosity of symmetrical stimuli was underestimated by about 6% in single task, and this bias was halved when attention was diverted by the concomitant dual task. Numerosity sensory precision (Weber fraction) did not vary between symmetric and random arrays in either the single or dual tasks, suggesting that the symmetry-driven numerosity underestimation and its reduction under dual task was not due to differences in sensory precision when judging random compared to symmetrical arrays. Taken together these results showed that the bias in numerosity perception of symmetric arrays depends on attentional resources and suggested that it might originate from the recruitment of grouping mechanisms, even in absence of extrinsic grouping cues.

Author PAMM was funded from the EUREGIO Interregional Project Network (IPN 135) - NeuroTrain: Neurocognition of arithmetic (re-)learning, Prot. 0000701(02-09-2021).

Motor and visuomotor numerosity channels derived from individual differences

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Recent evidence from psychophysical adaptation studies suggests that there exists a visuomotor numerosity system, activated by the numerosity of both external sensory events and internally produced actions. An alternative method to reveal perceptual channels is to look at individual variability. This technique, previously used to characterize channels for visual motion, spatial frequency, and other features, is based on the assumption that performance (e.g. thresholds) for pairs of stimuli detected by the same mechanism should correlate more than pairs detected by different mechanisms. These channels can be determined by measuring how correlations scale as a function of stimulus distance. Here we employed this technique to search for visual, motor and visuomotor numerosity channels. In the motor condition participants pressed a key a specified number of times (targets: N 8□32), while in the visual condition they were asked to interrupt a sequence of flashes when they reached the target. Counting was prevented by articulatory suppression and fast temporal rates. Estimation/reproduction precision was indexed as Weber Fraction (WF: error normalized by numerosity). For both visual and motor tasks, the results revealed high positive correlations between numerically similar stimuli, which steadily decreased as a function of numerical distance. For both modalities, a Principal Component Analyses revealed two main channels, one for low (N□16) and one high (N□30) numerosities. The analysis was little affected by the rate of motor reproduction, pointing to numerosity rather than temporal frequency. Importantly, the correlations between WFs across sensory modalities showed a clear numerical distance effect, pointing to shared mechanisms between perception and action. Overall, the results build on human and animal studies supporting the existence of a motor numerosity system, and show that this mechanism can be quantitatively characterized by simply examining the natural interindividual variability.

Acknowledgements: European Union (EU) and Horizon 2020—Grant Agreement no. 537 832813—ERC Advanced "Spatiotemporal mechanisms of generative perception—GenPercept" and talian Ministry of Education, University, and

Research under the PRIN2017 program (Grant no. 2017XBJN4F—"EnvironMag").

A Bayesian model for the estimation of the number of hidden objects

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Occlusion is ubiquitous in our visual environment and leads to a lack of sensory information about (partially) occluded objects. Accurately estimating the number of objects in a scene however is important for many mundane tasks, for instance to avoid crowded coaches on the train or to select the tree with the most fruits. In a previous study, we showed that humans underestimate the number of hidden objects, even when they accurately estimate the number of visible objects and the proportion of occlusion in the scene.

Here, we describe a Bayesian model predicting the number of hidden objects, based on the number of visible objects and the proportion of occlusion. A hypergeometric distribution is used to estimate the likelihood of visible number given a total number and the proportion of occlusion. This likelihood is then combined with a prior about the total number, which can be constant either for the total number of objects or the number of hidden objects. Combining the likelihood and the prior yields the posterior of the total number given the visible number. The model can account for the underestimation of the number of hidden objects with two free parameters, the location and the width of the prior. For about one third and two thirds of

participants, respectively, the prior was constant for the total number of objects or constant for the number of hidden objects.

The Bayesian model shows that the underestimation of the number of hidden objects is caused by a high uncertainty in the likelihood, which is completely determined by the statistics of the scene and a prior for a low number of (hidden) objects. Future studies will need to manipulate the scene statistics to understand how it affects the prior.

Acknowledgements: This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 101001250).

Temporal recalibration of sensorimotor contingencies of saccades can result from visual information alone

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Sensorimotor contingencies reflect a causal relation between movements and their sensory consequences, requiring that the active visual system accurately infers cause and effect. Adaptation to systematic delays between motor acts and perceptual events is known to calibrate such inferences. Here we investigate whether temporal recalibration between saccades and saccade-induced visual consequences requires the motor act or can be achieved by saccade-like visual stimulation alone.

In a first session, observers executed horizontal saccades across a noise background that triggered a high-contrast Gaussian ellipse visible as a flash during or after the movement. In a second session, observers fixated as the background moved according to amplitude-duration relation of previously recorded saccades, reproducing the same temporal relations of flashes and saccades. In both sessions, observers reported if the perceived flash appeared before or after movement offset. To test the effect of different consistent delays, two delay distributions for flash timings—either 20 ms or 80 ms after movement onset—were applied in separate blocks (60% of trials in each block). In the remaining trials, flash delays varied systematically.

We tested these conditions in two experiments. The first experiment applied a method of constant stimuli, resulting in trials with flash onsets from -40 ms to 160 ms relative to movement offset in which reports were always collected. In a second experiment, delays adapted to participants' responses by means of a staircase procedure, while dedicated inducer trials were used to induce recalibration.

In both experiments, we found that flashes were more frequently perceived as occurring before saccade offset when (inducer) flashes were consistently delayed. This demonstrates that systematic sensory delays associated with saccadic eye movements were rapidly learned. Crucially, we found a similar, but weaker effect for simulated saccades, suggesting that saccade-like visual motion may be sufficient to drive temporal recalibration, and possibly establish causality.

Supported by European Research Council (grant No 865715) and Deutsche Forschungsgemeinschaft (grants RO 3579/8-1 and RO 3579/12-1) granted to MR.

Temporal dissociation of localization and categorization tasks in Continuous Flash Suppression

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An advantage of Continuous Flash Suppression (CFS) compared to binocular rivalry is that the stimuli of interest can be compared in a more standardized manner, because they are rivaling against the same mask. In contrast, stimulus – mask arrangements across CFS studies consist of rather heterogeneous sets of parameters. Here, we conducted two experiments in which the fading-in speed of the stimuli was varied systematically while the performance in alternative choice tasks of different complexity was compared. Subjects judged stimulus position (left vs. right from fixation) as a lower level stimulus attribute, along with basic-level category (face vs. house; Experiment I) and orientation (upright vs. inverted; Experiment II) as two higher, object related attributes. To address the effects of temporal summation, target image contrast was faded in at rates ranging from 1/sec to 0.125/sec, while presentation was terminated after predefined contrast levels were reached. Thus, observers were exposed to brief and longer CSF interval durations, which changed randomly during the experiment. "Threshold" contrasts, derived from psychometric curves for a 75% accuracy criterion, were notably higher in both object related tasks for high contrast change rates, but reached same saturation values as in localization for slowly changing contrasts and longer trial durations. In a non-dichoptic control task there was constant advantage of localization compared to the object-related judgement, independent of contrast change rate. The larger slopes of threshold contrast functions for the object-related judgements in CFS indicate a higher efficiency of temporal integration, compared to localization. The findings support interaction of suppression with processing at higher and lower stages of the visual hierarchy, while processing at the level of object category benefits stronger from information accumulation over time.

Accelerating Visual Self-Motion is not Misperceived as Gravity when Judging Body Orientation on Earth or in Space

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When judging body orientation, the vestibular system provides us with information about the direction of gravity, while visual cues usually give cues about the relation between the body and the environment, both of which are integrated to provide a unified percept of upright and the direction of gravity. Physical acceleration can sometimes be confused with gravity (the somatogravic illusion). Can humans also reinterpret visual acceleration cues (vection) as gravity? If so, experiencing accelerating visually-induced self-motion (but not constant velocity self-motion) should impact subsequent estimates of body orientation – especially in the microgravity of space. To test this hypothesis, we immersed a cohort of 12 astronauts and a cohort of 20 control participants in a virtual hallway environment in which they experienced lateral self-motion, either at constant speed or at constant acceleration (0.8m/s/s) for 20s. They then set the orientation of the virtual floor to match where it was before the motion to indicate their orientation relative to that floor. The astronauts performed this task before, during and after their space flights, while the control participants were tested at similar intervals. Unexpectedly, we found that self-motion at a constant speed (but not at constant acceleration) had a small but significant impact on their perceived orientation when tested in space but not during any test sessions (by astronauts or controls) on Earth. We conclude that visually perceived self-acceleration is not misinterpreted as gravity – contrary to our hypothesis. Some of the potential mechanisms by which self-motion at constant speed might impact perceived body orientation will be discussed.

Tracking the dynamics of emerging neural representations via movement trajectories

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Deriving meaningful categorical representations from sensory inputs is critical for effective behaviour in complex and constantly changing environmental conditions. Non-invasive neuroimaging methods are the de-facto method for investigating such representations in the brain. However, they remain expensive, not widely available, time-consuming, and restrictive in terms of the experimental conditions and participant populations they can be used with. In the present study, we show that movement trajectories obtained from online behavioural experiments can be used to measure the emergence and dynamics of neural representations with fine temporal resolution. We show by combining online computer mouse-tracking and publicly available neuroimaging (MEG and fMRI) data via Representational Similarity Analysis (RSA) that movement trajectories track the evolution of visual representations over time. Online participants were asked to perform a time constrained face/object categorization task on a previously published set of images containing human faces, illusory faces and objects. The results revealed that time-resolved representational structures derived from their movement trajectories correlate with those derived from MEG, revealing the unfolding of category representations in comparable temporal detail (albeit delayed) to MEG. Moreover, we show that movement-derived representational structures matched those derived from fMRI in most task-relevant brain areas, faces and objects selective areas in this study. Our results highlight the richness of movement trajectories and the power of the RSA framework to reveal their information content to better understand human perception.

How unconscious retinotopic motion processing affects non-retinotopic motion perception

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In the retina and the early visual areas, the representation of the visual field is retinotopic, i.e., neighboring points in the external world are represented by neighboring neurons. However, perception is often non-retinotopic. For example, the trajectory of a reflector on the wheel of a moving bike appears as a closed orbit. In the external world and on the retina, it is a cycloid, i.e., a sinewave like function. We perceive an orbit because we perceptually "subtract" the horizontal motion trajectory of the moving bike from the cycloid. Here, we used the Ternus-Pikler-Display (TPD) to pit retinotopic against non-retinotopic motion similar as in the bike example. We, first, show that the retinotopic motion trajectory on the retina is fully processed in the visual brain. Hence, there are cortical presentations for the retinotopic and the non-retinotopic motion. Second, the retinotopic motion cannot be perceived consciously, i.e., observers were at chance level when discriminating whether the retinotopic motion was clock- or counterclockwise. Third, the invisible retinotopic motion influenced the percept of the conscious non-retinotopic one. When both motion directions were the same, e.g., clockwise, conscious motion discrimination was much better than when they were in opposite directions. Our results show clear evidence for highly sophisticated

unconscious processing periods with durations of at least 400ms. We will discuss the implications for motion processing, the time course of a conscious percept, and present a model about the underlying neural processes.

Can you learn not to respond to irrelevant motion while making fast arm movements?

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If the target of a goal-directed arm movement is suddenly displaced, the movement is quickly adjusted towards the target's new position. Surprisingly, if it is not the target's position that changes, but the background that suddenly starts moving, goal-directed movements are adjusted in the direction of the background motion. We wondered whether people could learn not to respond to such background motion. We therefore asked participants to intercept targets that moved across a background on a large screen. Using an interception task ensured that participants could not simply ignore visual information altogether. Participants started with their finger at an indicated position. They were to lift their finger when the target appeared and to tap on the target when it was within an indicated region. At a predictable moment before the target reached this region, the background either started moving to the left or to the right. Twelve naïve participants were each exposed to over 1000 trials, split across 5 sessions. We examined whether and to what extent the response to background motion declined across trials. We found a clear decline, especially during the first few hundred trials, but participants continued to respond to the background motion until the end. In the fourth and fifth sessions their average response was about 40% of the average response during the first session. Thus, participants can reduce the extent to which they respond to irrelevant motion, but they do not appear to be able to suppress such responses altogether.

Spatiotemporal profile of flash mislocalization in the vicinity of motion

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The perceived position of briefly flashed targets can be dramatically shifted in the presence of nearby motion. These flash-drag (Whitney & Cavanagh, 2000) and flash-grab effects (Cavanagh & Anstis, 2013) typically displace the perceived flash location when the flash appears when the motion reverses. Here we investigate the spatiotemporal profile of this motion-induced mislocalization when the motion is continuous (no reversals), and we test the role of expectancy.

While the observers fixated centrally, a radial bar rotated around fixation once at 1 cycle per second and a probe dot flashed at different locations relative to the bar. The observers reported the perceived location of the flashed probe at the end of each cycle with a mouse click.

The results showed that probes flashed within 10° (degrees of arc) in front of the moving bar were localized ahead in the direction of motion. The mislocalization was also seen for probes presented behind the bar but it gradually decreased to zero for probes about 10° behind the bar.

To see whether this asymmetry arises from the spatial distance between the bar and the probe at the time of flash or from the temporal offset between the flash and the "sweep" of the bar over the probe's location we reduced the angular speed of the rotating bar by half. The slower speed produced a smaller motion-induced shift, suggesting that timing is the causal factor.

Finally, we asked if the mislocalization can be explained purely by bottom-up visual signals. We observed that the mislocalization was reduced when the rotation direction of the moving bar was randomly selected in each trial, compared to when it was constant.

Overall, it seems that a motion-induced mislocalization is explained by the temporal distance between the flash and the sweep, and that non-sensory information contribute to regulating it.

Pre-saccadic alpha power is predictive of serial dependence in orientation judgement.

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Serial dependence, the assimilative bias caused by previous sensory experience on current perception, is usually taken as a clear demonstration of the action of predictive perceptual processes. In natural viewing, saccadic eye movements cause sequential sampling of the world, where successive images should drive serial dependence, a probable mechanism of visual continuity. Both theory and evidence suggest that the neural signaling of predictions may be mediated by alpha rhythms.

To study the role of alpha rhythms, we measured serial dependence for stimuli at the time of saccades, while monitoring EEG from 32 scalp electrodes. While making large (16°) horizontal saccades to a saccadic target, participants judged the orientation of a brief (17 ms) Gabor patch (±35°, ±45° or ±55°), presented at screen center at random delays after saccadic target appearance. This design allows for testing serial dependence

mechanisms on trials where the previous stimulus was of similar orientation (within 20º). We divided these trials into two groups, attractive (reflecting serial dependence) and repulsive.

EEG traces (synchronized to saccadic onset) oscillated reliably in the alpha range (8-14 Hz), clearly visible in the artifact-free pre-saccadic period for post-saccadic stimuli. However, alpha power was significantly stronger for the attractive than repulsive trials, especially over the occipital electrodes, suggesting that pre-saccadic alpha power is related to serial effects in perception.

Our results show that alpha rhythm power predicts the magnitude of serial dependence at the time of saccades, suggesting they play a key role in communication of visual predictions and trans-saccadic continuity.

Serial dependencies for external and self-produced stimuli

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Our senses are constantly bombarded by stimulation from the external world. Many stimulus features can be detected with only low certainty. A recent stream of research has revealed that the estimate of currently sensed features serially depends on features previously detected. The functional role of serial dependencies might be the stabilization of vision by a reduction of uncertainty and a smoothening of perception across discontinuities. However, in natural vision we are not merely passive observers but actively exploring our environment. By moving we also produce sensory stimulation, for instance visual motion on the retina when moving the eyes or tactile sensations when accidentally touching something. The need to distinguish self-produced from external stimulation, research suggests, is fulfilled by a sensory attenuation of self-produced stimuli. Importantly, sensory attenuation does not fully cancel out perception for the respective stimuli but reduce processing. If the mechanism that orchestrates serial dependencies plays a functional role in perception, it should be informed about stimuli that are represented only weakly because of sensory attenuation. Here, we investigated serial dependencies for the spatial localization of self-produced and randomly timed stimuli. Participants in the self-produced condition pressed a button and a visual stimulus appeared on the screen for 20 ms. After the stimulus disappeared, subjects localized the perceived position of the stimulus with a mouse pointer. In the externally produced condition, participants also pressed a button but the stimulus occurred between 1000-3000 ms after the button press. Such condition does not generate sensory attenuation. We found serial dependencies only in externally, but not in self-produced conditions. A confounding factor that differs between self-produced and randomly timed conditions is temporal predictability. In further experiments we isolated that factor and found that serial dependencies were not modulated by temporal predictability. We conclude that the mechanism generating serial dependencies is informed about sensory attenuation, confirming the idea of the functional role for stabilizing perception.

Serial dependence in orientation perception in adults with autism spectrum disorder

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Recent studies have suggested that atypical perception in autism spectrum disorder (ASD) can be attributed to atypical predictive coding such as decrease in prior precision or increase in sensory precision. However, it remains unclear which stages of the perceptual system are atypical in predictive coding. Serial dependence in orientation perception means that perceived orientation in n trials is attracted to perceived orientation in n-1 trials. This is known as an example in which current perception shifts toward prior perceptual experience. This study examined the difference in serial dependence in orientation perception between ASD and typical development (TD), in two stages: sensory encoding and perceptual decision. Participants were 22 adults with ASD and 24 adults with TD, matched for age, sex, and IQ. Perceived orientation was measured using method of adjustment. In odd trials, orientation of a Gabor patch was reproduced by rotating a white bar. In even trials, orientation of its mirror was reproduced. For the similar stimulus condition, a right-tilted Gabor patch was always presented, thus serial dependence would arise at the sensory encoding stage because of the similarity between n-1 and n stimuli. For the similar response condition, a right- and left-tilted Gabor patch were alternately presented, thus serial dependence would arise at the perceptual decision stage because of the similarity between n-1 and n responses. The results showed that serial dependence was significantly lower in ASD than in TD for the similar stimulus condition, whereas it was equivalent between ASD and TD for the similar response condition. In addition, precision of reproduced orientation was equivalent between ASD and TD for both conditions, indicating comparable sensory precision in ASD and TD. These findings suggest that atypical perception in ASD is attributed to decrease in prior precision at the sensory encoding stages, at least with respect to orientation perception.

Serial dependencies in visual stability during self-motion

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Our head and eyes are constantly moving. Gaze shifts generate the biggest and the most frequent disturbance of vision.

Displacing the eye sweeps the external scene across the retina, leaving the brain to decide whether visual motion was self-produced or if it was due to changes in the external world. During head movements, the eyes counteract the visual motion produced by the head rotation by stabilizing the image on the retina. In order to correctly perceive motion in the external world and to keep vision stable, the sensorimotor system must cancel out the self-produced motion. Maintaining visual stability during gaze shifts is necessary for both, dissociating self-produced from external motion and retaining bodily balance. Vestibular, proprioceptive and efference copy signals inform about the speed of the head rotation. However, how is the mapping between these signals and the visual motion recalibrated to preserve precise predictions about the expected visual motion. We asked participants to rotate their head and manipulated the mapping between the physical head movement velocity and the velocity of visual motion that was shown in a head-mounted display. Participants were required to report whether they perceived the relative visual motion as faster or slower than what they would expect from their head movement. We found that the velocity at which the visual scene appeared stable depended on the velocity that was perceived in the preceding head movement. Our data suggest that predictions about the expected scene displacement velocity during a gaze shift are shaped by serial dependencies of visual motion. Further analyses revealed that motion in a retinal reference frame from the previous trial influences head-centered motion perception on a current trial. In conclusion, serial dependencies of visual motion organize visual stability during gaze shifts.

Serial dependence in dermatological judgments

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Serial dependence in visual perception is a bias in perception and decisions toward previously seen objects. It has been explored and replicated in many domains, including basic vision research and clinically relevant settings. It could be especially problematic in clinical settings where multiple unrelated images are viewed and screened in succession for diagnostic purposes. A striking example of this is remote store-and-forward teledermatology, where clinicians are asked to make sequential visual judgments about multiple images. Here, we investigated whether there is serial dependence in perceptual evaluations of skin lesions in a set of over 700k trials. The data were collected from a mobile app and included 2AFC (malignant/benign) judgments made by medical students, interns, and medical doctors. We found that there was significant serial dependence in the dermatological judgments, with an increase in error rates of up to 4% for sequentially similar images and a corresponding reduction in hits and increase in false alarms. These net changes were attributable specifically to serial dependence. Serial dependence is not just repeated button presses, nor is it captured by simply measuring signal detection metrics like d' or criterion over blocks of trials—serial dependence is a trial-wise nonlinear bias such that only sequentially similar things seem even more similar than they actually are. Our results are consistent with this, revealing serial dependence on a trial-by-trial basis only for similar sequential images, not for sufficiently different images. The serial dependence we found in the dermatology judgments was also temporally tuned. The results suggest that serial dependence can occur in clinically realistic screening practices; it can significantly impact sensitivity, specificity, and error rates; and it can be mitigated by altering the sequence of presentation.

Explicit and Implicit Ensemble Perception: Same or Different

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Visual scenes are too complex to immediately perceive all their details. As suggested by Gestalt psychologists, grouping similar scene elements expedites evaluating scene gist. Ensemble perception efficiently represents similar objects, overcoming processing, attention and memory limits. Observers are better at perceiving image set means than remembering presence of set members. Ensemble perception occurs explicitly, when observers judge set mean, and automatically, implicitly, on-the-fly, trial-by trial, when engaged in an orthogonal task. We are studying relationships among these ensemble perception phenomena, testing explicit and implicit ensemble perception; for sets varying in circle size, line orientation, or disc brightness; and with spatial, temporal or spatio-temporal presentation. Following presentation of an ensemble set, 55 observers judged which of 2 test images had been present in the set. Subsequent tests asked them to explicitly judge which of 2 test images was closer to the mean. We found that image presence judgement followed a Gaussian dependance on distance from mean and sigmoidal dependence on relative distance from mean; explicit mean judgement had a sigmoidal dependence on relative distance from mean. We compare these dependences finding that explicit ensemble averaging is more precise than implicit mean perception, though individual differences analysis shows common underlying mechanisms.

Support: Israel Science Foundation (ISF)

Psychological Effect of Color and Aroma of Olive Oil on Predicted Taste and Deliciousness

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It is necessary to reveal the multi modal effect of color and aroma of olive oil because olive oil become also very popular in Japan. Three experiments were conducted to reveal the effect of color and aroma of olive oil on a psychological evaluation before eating. Twenty university students sat in the black room whose size was 660W x 850D x 1460H mm, and looked at the monitor shown an oil in the dish at a depression angle of forty degrees. In Experiment 1, they observed the generated digital images of five colors of olive oil in a white dish, red, orange, yellow, yellow-green and green. In Experiment 2, they sniffed olive oil in a bottle with five aromas (flavors), lemon, orange, vanilla, peppermint and matsutake mushroom. Aroma bottles were put in the black box so that the inside could not be seen, participants sniffed the bottles with putting their head close to the box. In Experiment 3, they observed each digital image while sniffing each aroma multimodally. Participants evaluated predicted sweetness, sourness, saltiness, bitterness, umami taste, predicted deliciousness, and six impression items. In Experiment 3, most participants rated the combinations of yellow-green olive oil and lemon, orange and vanilla flavor as most delicious combinations. The multimodal evaluation (Z) was assumed to follow a model formulated as $Z = aX + bY$, where a and b were weighting factors, X was the visual evaluation and Y was the olfactory evaluation. The contribution ratios (b/a) of aroma to color in predicted deliciousness was 0.58. The present result was characterized by a larger visual coefficient ($b/a<1$) compared to previous studies in which a similar study was conducted on various beverages. The contribution ratios may depend on how the foods and beverages are consumed.

Congruent sounds enhance the visual perception of actively masked biological stimuli

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Several examples in the literature indicate how audio-visual integration may arise during the transition from unconscious to conscious visual perception. Moreover, the spatial, temporal, and semantic congruency between sensory modalities has been shown to shape the resulting perceptual experience. Here we investigated how semantic congruency between action sounds and visual biological motion stimuli influence the perception of ambiguous visual stimuli. We suppressed dynamic biological motion videos depicting human actions (rowing, sawing, walking) from consciousness using continuous flash suppression while presenting congruent, incongruent or no action sounds. Visual stimulus contrast was individually thresholded via a Bayesian staircase procedure. We measured moving dot detection rate with a 2-AFC task and accuracy of action type categorization. Preliminary results show that participants detected dot motion significantly faster and more accurately when congruent sounds were presented when the stimuli where biologically plausible (i.e. upright instead of inverted). These results show that congruent sounds can boost biological motion stimuli into visual awareness. Thus, semantically congruent sounds seem to be sufficiently integrated to enhance the access of visual stimuli into awareness.

Visuo-haptic multisensory integration in actions toward oriented objects

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Our actions are guided by sensory information we receive from the environment. When different senses provide complementary information about an object, our brain integrates these inputs to create a single, unified perceptual experience, which is often more accurate, precise, and robust than the information provided by each individual sensory modality alone. As a result, movements guided by multisensory information are also more efficient. Previous research on multisensory integration in actions has mostly considered the integration of cues related to object size and its position. Therefore, it is still unclear whether the benefits of multisensory integration extend over other stimulus proprieties. To fill this gap, we investigated how and to what extent the visuo-haptic integration of stimulus orientation affects actions. Participants were asked to place an object flush onto a flat target object surface mounted on a robotic arm which presented it at different orientations. In the visual condition, movements were guided by visual information only. In the haptic condition, participants were required to hold the target object with their left hand before and during movements, relying solely on haptically perceived stimulus properties (position and orientation) as vision was obstructed. In the visuo-haptic condition, participants could both see and feel the target object. We focused our analyses on the trajectory of the performed movements and, more specifically, on the orientation of the object with respect to the target object at the moment of contact. In line with previous studies, we found a clear advantage of the visuo-haptic condition with respect to the other unisensory conditions. These results extend our previous knowledge about the use of multisensory information in actions and highlight the importance of multisensory integration for motor control.

Cue Combination in Weight Perception with Familiar and Novel Cues

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Efficient combination of cues redundantly present across sensory modalities can enhance perceptual precision. Although the size-weight illusion suggests that visual and haptic object information interacts to create a final weight percept, it is unclear how this is combined in more natural, congruent, settings. Here, we investigate whether the combination of visual and haptic weight cues can enhance the precision of weight perception. First, we test this with a familiar visual cue, and secondly, with a novel visual cue. We hypothesised that weight discrimination using both visual and haptic cues will be more precise than with either individual cue.

In the first experiment, 32 participants performed a forced-choice task in three conditions, on each trial judging which of two transparent jars containing sand is heavier. In the visuo-haptic condition, participants held the jars while viewing their contents. In the visual condition, participants only viewed the jars and their contents. In the haptic condition, participants held the jars without seeing their contents. In the second experiment, the visual cue was changed so that instead of having their contents visible, jars were textured with line orientations mapped to their weights. Participants were first familiarised with this novel weight-to-orientation mapping in 90 minutes of training.

In the first experiment, performance was significantly better with visual and haptic cues together compared to the best individual cue alone ($p < .001$). This suggests that weight perception can be enhanced through cue combination with a familiar visual cue. Data collection for the second experiment is underways. Preliminary data from 5 participants shows that all participants successfully learned the weight mapping, obtaining precision comparable to their haptic-only judgments. Comparing these results with those from the first experiment will let us draw new conclusions about the degree of flexibility for learning new cue mappings for efficient perception and action.

The eyes are captured by animate images without conscious visual perception

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It has long been recognised that images suppressed from visual awareness nevertheless have perceptual and behavioural effects. Complementary eye gaze data demonstrated that in the absence of visual awareness, content-specific images, e.g., emotional faces can guide oculomotor responses differentially according to emotional expression. Here we investigated whether images along the animate/inanimate distinction would differentially guide oculomotor responses in the absence of visual awareness, too. Since sensory information occurs mostly multimodally in the natural environment, we also tested whether naturalistic sounds congruent or incongruent to the suppressed image affected threshold-level visual processing and its contingent oculomotor responses. Using continuous flash suppression, we suppressed static images of human hand clapping and inanimate motorcycles from observers' awareness while simultaneously presenting image-congruent or -incongruent sounds or no sound. We thresholded image contrast level individually. Participants completed two-alternative forced choice tasks on image position and image category (objective measures of awareness) and rated the image's visibility (subjective measure of awareness). Meanwhile, we tracked observer's eye movements, and analysed the changes in gaze position during image presentation. Under successful visual suppression, as indicated by the behavioural measures, preliminary results showed that eye gaze rested more on animate human hand images than on inanimate motorbike images. Sounds did not show a specific effect on this oculomotor behaviour. Our findings reveal that human hand images attracted gaze more so than images of inanimate motorbikes despite being suppressed from awareness, suggesting that animate/human visual information may be better at guiding oculomotor responses in the absence of awareness than inanimate visual information. This suggests that animacy is a potentially powerful feature that guides eye movements even in the absence of visual awareness.

Image-to-audio generation as a tool for stress relief

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Recent advancements in technology and machine learning, allow straightforwardly producing images, music, and text. This research evaluates the relaxation and calmness state induced by AI-generated audio from an image without human supervision. The image-to-music process consists of the following steps: (i) generate a text description of an input image using Blip2 vision-language pre-training (VLP) model (Li et al., 2023), (ii) improve the generated text with more descriptive details using OpenAI ChatGPT large model language for a better audio quality generation, (iii) synthesize audio output based on generated text description using AudioLDM text-to-audio model (Liu et al., 2023). The generated audio from a set of meditation images was tested on 17 participants (aged 26-43 years) as a stimulus for audio-guided relaxation. The level of relaxation and calmness (scaled from 1 to 1000) was evaluated using a portable single-channel dry electrode Neurosky Mindwave EEG system placed on the user's forehead. The Lucid Scribe software can measure "Meditation" values corresponding to the user's level of relaxation and calmness. The measured mean values of the participants were between the ranges of 400 – 800 (average=602,4), which corresponds to a slightly elevated relaxation level.

The effect of wearing a face mask on lip-reading and audiovisual speech perception.

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Seeing a facial speech plays a crucial role in allowing listeners to understand a person's speech. However, since the outbreak of the COVID-19 pandemic, the use of facial speech has become more difficult because most people routinely wear masks to prevent infection. In this study, we investigated whether and how wearing a mask altered reliance on facial speech in audiovisual speech perception. Specifically, we compared the task performance of Japanese adults in audiovisual speech recognition (i.e., the McGurk effect) and lip-reading before and after the pandemic with a cross-sectional study. We collected pre-pandemic data (N=30) between June and July 2019 and post-pandemic data (N=21) from November 2022. The results showed no significant differences in accuracy between pre- and post-pandemic data for lip-reading or recognition of audiovisual congruent speech. Additionally, the amount of McGurk effect (i.e., the amount of visual reliance) in the post-pandemic data was comparable to that in the pre-pandemic data. These results imply that the perceiver's strategy of relying on facial speech during audiovisual speech processing did not significantly change between before and after the outbreak of the COVID-19 pandemic.

Dimension-based distractor handling in visual search: evidence from behavioral and electrophysiological measures

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When searching for a target, salient distractors can capture attention and interfere with the search process. It remains controversial how we handle such distractor interference. Some suggest that we proactively suppress bottom-up distractor signals, while others argue that we reduce engagement with the distractor. To explore this issue, we conducted two experiments. In the first experiment, we adopted an additional singleton paradigm with a salient distractor defined in the same shape dimension as the target (within-dimension), a different color to the target (cross-dimension), or a different tactile modality (cross-modality). The target and the distractor were displayed on opposite sides. We assessed behavioral search interference and measured lateralized electrophysiological components (N2pc, PPC/Pd, CCN/CCP) to evaluate attentional selectivity. We found distractors sharing the target's shape dimension caused the most interference and attentional engagement to the distractor, as indicated by the smallest target-elicited N2pc when both target and distractor were presented and the largest distractor-elicited N2pc when the target was absent. By contrast, cross-dimensional and cross-modal distractors did not produce significant interference but could still induce significant early sensory processing. The target-elicited N2pc was comparable among the distractor-absent and the cross-dimensional and cross-modal distractor-present conditions. The early sensory processing components, such as Ppc and CCN/CCP for the cross-modal condition, were activated but did not influence the target-elicited N2pc, suggesting that the distractor did not receive any further attentional resources. To disentangle potential confounding caused by both lateralized distractor and target, in Experiment 2, we lateralized either the target or the distractor while keeping the other in the midline. Same as in Experiment 1, we varied the distractor dimension and modality. The results of both experiments were consistent and suggested that the attention system cannot down-weight target-related dimensions, but it can down-weight non-target features and dimensions rather than active suppression.

Examining Auditory Modulations on Detecting and Integrating Visual Global Motion

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Multisensory signals often interact and influence each other to reduce perceptual uncertainty in the environment. However, contradictory results exist regarding the effects and mechanisms underlying audiovisual motion perception. Here, we adopted the constant stimuli method and the equivalent noise paradigm to investigate whether and how auditory motion influenced the perception of visual global motion. The visual global motion consisted of dots in which the moving directions were sampled from a normal distribution with five levels of standard deviation. The auditory motion comprised a white noise moving in the congruent or incongruent direction with visual global motion, or else the sound was stationary or absent. Participants had to discriminate the direction of the visual global motion. The results demonstrated that after separating or eliminating the bias that the auditory motion induced at the decisional level, the thresholds of visual motion perception were similar under the four sound conditions. Further analysis based on the equivalent noise model demonstrated that the auditory motion did not modulate detecting or integrating the visual motion signals. In conclusion, we did not find evidence

supporting auditory modulations on the sensory/perceptual processing of visual global motion.

The role of visual and auditory information in the identification of the type of tennis serve: A pilot study

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Research on the cognitive processes involved in the perception and execution of complex movements devoted far greater attention to the visual domain than to the auditory one. However, since the beginning of the new millennium, there has been a growing interest toward the role of auditory information deriving from biological motion, as a series of studies highlighted that this information can influence the abovementioned processes to a significant extent. In particular, as concerns sports, a process that benefits (also) from auditory information is the anticipation of opponents' actions and of their outcomes, especially in terms of quantitative parameters (e.g., shot power). In this regard, the aim of the present pilot study was to investigate whether auditory information can also contribute to a qualitative judgement, i.e., the identification of the type of tennis serve. To this purpose, 41 amateur tennis players (age: M = 23.2 years, SD = 6.5; experience: M = 9.9 years, SD = 5.8) were asked to identify the type – flat, slice, or kick – of temporally occluded tennis serves, relying only on either visual information (video condition) or auditory information (audio condition). Overall, even if response accuracy was higher in the video condition, it was above the chance level also in the audio condition; dividing participants into two groups based on their expertise (ranking position), those with higher expertise had higher accuracy in the video condition, and in the same condition they had higher accuracy than those with lower expertise. As for response time, no overall differences emerged, yet in the video condition participants with higher expertise were faster than those with lower expertise. Taken together, these results suggest that auditory information can significantly contribute also to qualitative judgements in sports, an outcome that deserves further research aimed at understanding practical implications in terms of performance improvement.

Internal and external triggers modulate ambient & focal processing of scenes and website pages

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Visual exploration, by essence, is dynamic and evolves over time by oscillating between two modes of processing: a first ambient mode (shorter fixations and larger saccades) which allows us to obtain general information concerning the global spatial organization of a visual stimulus followed by a switch to a focal mode (longer fixations and smaller saccades) which allows to obtain more advanced information through deeper processing. This dynamic has been characterized through the K coefficient calculated from fixation durations and saccade amplitudes. Also, recent studies have shown that the dynamics of these two modes, linked to distinct cognitive processes, were influenced by different factors such as the task or a change in a stimulus. Thus, these factors have a triggering role in the dynamics modulation of visual exploration.

Here we collected eye movements from 44 participants performing free-viewing and target-searching tasks on both images of visual scenes (considered as statics) and website pages (considered as dynamics due to the possibility of scrolling). Our goal was to study how an internal trigger (when a target is found) and an external trigger (when a change of stimulus is induced by a scroll) could influence the visual exploration dynamics. Preliminary results, based on temporal event-based analyses, suggest that both types of triggers have an influence on the dynamic of visual processing with a tendency to switch back to ambient mode after a trigger has occurred. For the first time, our study presents a new key to further understand the dynamics of visual processing over time, beyond the well-known first ambient to focal processing switch.

Visual and haptic pleasantness of geometric patterns

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While the visual perception and experience of geometric patterns, such as abstract patterns or patterns found in the built environment, has been studied extensively, relatively little is known about how they are perceived and experienced haptically. In this study we compared visual and haptic pleasantness ratings of abstract patterns in the form of raised line drawings. In vision, pleasantness has been shown to relate to complexity following an inverted U-curve or, more recently, to linearly relate with complexity depending on individual preferences. In addition, research on patterns of shading systems suggests that pleasantness also relates to naturalness, i.e., to how much a pattern is associated with nature. Therefore, we compared pleasantness, complexity, and naturalness ratings of geometric patterns between vision and touch. The stimuli were 15 geometric line patterns varying in shape and line orientation, and thus also

in expected complexity and naturalness. Twenty participants rated the patterns using free magnitude estimation. Participants first explored the patterns only haptically with their index finger, and then only visually. This order was chosen to prevent recognition of the patterns, which is much easier visually than haptically. A linear mixed model showed that both perceived complexity and naturalness significantly predicted pleasantness for both the haptic and visual modalities. For both modalities, naturalness was positively related to pleasantness, while complexity was negatively related to pleasantness. However, pleasantness was higher in the haptic condition, and modality significantly interacted with complexity but not naturalness. This suggests that touching instead of seeing a pattern can affect perceived pleasantness. These insights are useful for the design of patterns that are meant to be both seen and touched.

Second-order spectral space : a common computational scheme underlying visual and auditory texture perception

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In the natural environment, we see various textural images such as grass and gravel, and hear textural sounds such as the blowing wind or rushing water. The information of such textures is not only an important cue for estimating external objects and events, but also a fundamental basis for our rich and complex perceptual awareness. Here, we show that both visual and auditory texture perception can generally be explained by first- and second-order global spectra of sensory input over a specific spatial/temporal range (c.f., Okada & Motoyoshi, 2021, Front. Comp. Neurosci., 15, 692334.; Maruyama et al, in press, iPercept.). For vision, the appearance of a natural texture image can be described by a 2-D luminance spectrum (Fx, Fy) and a 4-D subband energy spectrum (Fx, Fy, Fori, Ffreq). For audition, the hearing of a natural texture sound can be described by a 1D spectrum of sound waves (Ft) and a 2D envelope spectrum (Ft, Ffreq). We show that random noise images and sounds that preserve the two spectra are perceived similarly to the original textured images (e.g., cloth, wood) and sounds (e.g., water, bells), suggesting the robust predictability of the model. The spectral representations, which are mathematically analogous to Portilla-Simoncelli and McDermott-Simoncelli models based on various classes of image/sound statistics, allow us to represent natural texture images and sounds in only two spectral spaces. We also demonstrate that this simplicity can be used to easily visualize the first- and second-order frequency characteristics that determine specific perceptual impressions (e.g., heaviness, smoothness) of natural texture images and sounds. These findings suggest a common computational principle underlying visual and auditory texture perception.

Neutral grey judgements as a tool to reveal odour-colour correspondences

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Background. Odours are often perceived together with visual cues and both of these sensations interact to modulate the subjective experience. Odours are commonly and consistently matched to different colours predominantly stemming from knowledge of the identity of the odour (REF to your paper here). These crossmodal correspondences are presumed to be bi-directional in nature. Methods. We explored the effect of different odours on human colour perception by presenting olfactory stimuli while asking observers to adjust a colour patch to be devoid of hue (neutral grey task). Our expectation was that the neutral grey settings would reveal a shift in the colour opponent to the one associated with the particular odour. Results. We found that the presence of different odours induced a bias on what the observer thought was a neutral grey. Contrary to our expectation, the hue angles of the neutral grey settings predominantly pointed towards each odour's anticipated (and previously established) colour correspondence. For example, when asking observers to perform neutral grey settings while a coffee odour was presented, the perceptually achromatic stimulus was biased towards yellow-brown; for a cherry odour the settings were biased towards pink-red. The colour shifts are generally small, around 1 unit in LAB space. Conclusion. Using an achromatic adjustment task we were able to demonstrate a small but systematic effect of the presence of odours on human colour perception.

Reduced contextual effects and sensory specialization in duration perception in autism

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Autism is a neurodevelopmental disorder of unknown etiology. Recently, there has been a growing interest in sensory processing in autism as a core phenotype. However, basic questions remain unanswered. We examined here whether altered perception of magnitude in autism arise from modulations in biases and contextual effects known to calibrate perceptual sensitivity in neurotypicals. We have recently shown that both the visual and the auditory modalities use within-sensory modality (but not between-modalities) contextual information to

calibrate sensitivity of duration perception. We examined these contextual effects on duration perception for visual and auditory stimuli where context was manipulated within- and between the sensory modalities. People with and without autism preformed a two-interval forced choice task to determine the longer of two temporal signals either visual or auditory. Participants performed the task under three conditions. 1) The central standard was presented in 2 types of modalities: visual or auditory. 2) The contextual standards formed either a wide or a narrow contextual range around the central standard. 3) The contextual standards were presented in 2 types of modalities: visual or auditory independent of the central standard ("same-modality" or "between-modality"). Thus, eight conditions were tested for the central standard, and for each, JNDs were measured using a QUEST interval staircase method. We show that in neurotypicals, the narrower context enhanced sensitivity for standards within the same modality but had no effect on standards of another modality, suggesting that perceptual magnitude normally leans on an underlying modality specific calibration process. An advantage for the auditory domain in duration perception also suggests sensory specialisation. However, people with autism showed no biases across all the conditions, and no advantage for the auditory modality, resulting in an enhanced perception for some conditions. Altogether, the results suggest modulated contextual effects and sensory specialization in duration perception in autism.

Pupillary measures of audio-visual binding can predict the varied severity of motion sickness

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Background: Motion sickness (MS) refers to the feeling of sickness that typically occur during travel, with varied severity across individuals. Current explanations focus on the sensory conflict in the perception of motion, primarily between the vestibular and the visual systems. We have previously suggested that people tend to feel motion sickness when the conflicting stimuli are perceived as bound together. We demonstrated this by showing a correlation between the severity of Motion Sickness and the temporal binding window (TBW) for the McGurk effect, which is the asynchrony window in which the effect persists. In the current study, we used an objective pupillary measure of the TBW applied to a different stimulus, the double-flash illusion.

Methods: Observers (N=25) passively viewed a single visual flash presented together with two loud beeps. To assess the time window of the audio-visual integration (TBW), we measured the decrease in the relative pupil dilation induced by the beeps with varied onset asynchrony between the beeps and the flash. The participants were also tested on the TBW in the McGurk stimuli and filled a common Motion Sickness questionnaire.

Results: The TBW obtained from the relative pupil dilation in passive viewing was positively correlated with the severity of MS obtained by the questionnaire (R=0.74). In addition, the TBW of the McGurk effect measured behaviorally was also correlated with the MS severity (R~=0.9) as we have previously found.

Conclusions: These results support our hypothesis that explains the enigmatic differences between individuals in the susceptibility to motion-sickness by differences in the width of the temporal binding window in multi-sensory integration. We show that these individual differences are not related to subjective perceptual criteria as they can be measured via pupil dilation in passive viewing. The results also demonstrate a novel pupil-based method for measuring the audio-visual TBW.

Verbal or visual representation of side effects: Does this affect the judgement of driving behavior?

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The over-the-counter medication you get at the pharmacy for your hay fever comes with a verbal warning that in rare cases, side effects such as blurred vision may occur. How does this warning affect your driving behavior (e.g., the assessment of the risk of a car accident)? Now, recent studies have shown that pharmaceutical pictograms, visual aids to the application, dosage, but also to the side effects of medications, improve their correct intake because, for example, they attract more attention. However, little is known about whether and how such pictograms influence risk perception. To investigate this, participants (N = 306) in an online study were shown a medication package that provided either visual (i.e., pictograms) or verbal information about the rare occurrence of side effects (factor: format). The number of side effects could be 1 or 3 (factor: number). Participants who were randomly assigned to one of the four conditions had to indicate the probability of a car accident (1 – 100%), and their driving intention (do not drive anymore, drive only a short distance of 30 minutes or less, drive a longer distance of more than 30 minutes) because of taking the medication. Regarding both dependent measures – probability of a car accident and driving intention – we found only significant main effects of format (both p's < .05). More precisely, with the visual presentation format of side effects, not only was the likelihood of a car accident rated lower than with the verbal presentation format (33.7 vs. 40.2%), but the willingness not to drive was also lower (9 vs. 15%). Note that across all conditions only 23.5% correctly rated "rarely" as being between 0.01 and 0.1%. Overall, a visual representation of side effects using

pictograms on a medication package seems to reduce risk perception.

Bayesian multilevel modelling of simultaneity judgements discriminates between observer models and reveals how participants' strategy influences the window of subjective synchrony

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When experimenters vary the timing between two intersensory events, and participants judge their simultaneity, a non-standard (i.e. non-sigmoidal, non-monotonic) psychometric function is obtained. Typically, this function is first characterised (i.e. fitted with a model) for each participant separately, before best-fitting parameters are utilised (e.g. compared across conditions) in the second stage of a two-step inferential procedure. Often, psychometric-function width is interpreted as representing sensitivity to asynchrony, and/or ascribed theoretical equivalence to a window of multisensory temporal binding. Here, we instead fit a single (principled) multilevel model to data from the entire group and across several conditions at once. By asking 20 participants to sometimes be more conservative in their judgements, we demonstrate how the width of the simultaneity function is prone to strategic change and thus questionable as a measure of either sensitivity or multisensory binding. By repeating our analysis with three different models (two implying a decision based directly on subjective asynchrony, and a third deriving this decision from the correlation between filtered responses to sensory inputs) we find that the first model, which hypothesises, in particular, Gaussian latency noise and difficulty maintaining the stability of decision criteria across trials, is most plausible for these data.

Semantic interaction between music and artworks

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The present study investigated both the capability of music and visual art to convey semantic meaning and the interaction across the two sensory modalities. Previous literature has shown that instrumental music can communicate iconic, indexical, and symbolic meanings, similarly to language. The stimulus set comprised 160 artworks and 16 musical pieces, belonging to 8 distinct semantic categories. Stimuli were also divided into highly distinctive (Lullaby, Dance, Battle, Requiem) and poorly distinctive (Play, Love, Tragic Love, Relax) categories. Half paintings were paired with semantically congruent or incongruent musical excerpts, in the hypothesis that listening to an incongruent background music would interfere with the semantic recognition of the visual stimulus. ERPs were recorded in 23 participants. Results show the N2 component, described as an index of novelty and mismatch, here indexing also conflicts in cross-modal incoming information. We also examined responses of the N400. In this case, this ERP component is shown in multimodal stimulation and is modulated by the ease of the categorization of the stimuli. Moreover, the interference in the semantic domain is also demonstrated across sensory modalities, shown in the modulation of the N400. Finally, the source reconstruction applied on the N400 time window highlighted the activation of the Superior Frontal Gyrus (SFG; BA 8) and the Inferior Temporal Gyrus (ITG; BA20). The former brain area was found to be involved in visuospatial processing and also in conflict monitoring. As participants were listening to a background music while watching an artistic picture, both these functions are implicated in our task and can explain this activation. ITG, on the other hand, was found to be involved in multimodal semantic integration. Thus, these data strengthen the hypothesis of a bidirectional modulation between visual and auditory channels and that semantic interference is a general cognitive mechanism.

Semantic Content Effects On The Perception Of Movieclips

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Crossmodal integration has been studied intensively by many perception researchers providing evidence of the influence of semantic sound on visual perception. However, prior experiments mostly utilized pictures and were limited in the semantic content of a single sound or word. This study aims to investigate crossmodal integration in realistic conditions using short movieclips (1500ms) and auditory meaningful three-word sentences. For this purpose, an online experimental task was developed using PsychoPy, where participants (N=13, age range 20-50) had to indicate whether a target was present or absent. In trials without a target, target-related information was always present, either through vision, audition, or through both. For each target condition (present or absent) the movieclips were made up of a combination of 6 videos and 6 sentences, which were repeated in a pseudorandomized order four times for each participant (total trials= 288). We observed superior performance when the target was absent (M=93.8%, SD=0.036) compared to when it was present (M=80.5%, SD=0.133). A two-

way repeated measures ANOVA showed that target presence (yes/no) had a statistically significant effect on individual performance ($F(1,12)=14.231$, $p=0.003$), as well as the modality (audition/vision/both) through which target or target-related information was presented ($F(2,24)=9.422$, $p<0.001$). We also found a statistically significant interaction between target presence and modality ($F(2,24)=11.276$, $p<0.001$). Post hoc tests showed that performance was worse when target or target-related information was presented as audio compared to visually ($p= 0.007$) or audiovisually ($p=0.001$). We also observed that in the audio condition, when the target-related word was a noun, participant performance was superior compared to when it was a verb ($M=99\%$ vs. $M=89.4\%$; $t(12)=5.196$, $p<0.001$). In accordance with previous research with images and single words, our results show that when auditory and visual information is congruent, performance is at the highest level and when the target is only present through audio but visual information is incongruent, performance is evidently compromised.

Spatial contextual cues can be used to guide interception

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Many objects in our environment do not move at a constant velocity but rather undergo sudden accelerations. We are very poor at visually judging acceleration and thus make systematic errors when trying to intercept accelerating objects. Does providing spatial contextual cues improve interception of an accelerating target? To answer this question, we asked participants to hit a target that moved within a disc, similarly to how a valve (target) moves on a bicycle wheel (disc). On half the trials, the disc was visible such that participants could use the spatial relations between the target and disc to guide their interception. On the other half of trials, the disc was not visible such that participants had to predict the target's complicated patterns of accelerations and decelerations to guide their movement. Importantly, the target always followed exactly the same trajectory. Participants hit more targets when the disc was visible than when it was invisible. This shows that spatial contextual cues can help interception of an accelerating target. The interception strategy differed considerably across participants. Those who consistently aimed to hit the target when it was in the same phase of its rotational movement, rather than at a fixed time after it appeared, hit more targets. This benefit was particularly clear when the disc was not visible. This strategy is presumably advantageous because it allows one to compensate for their errors on earlier trials in a manner that does not require judgements of acceleration. We conclude that spatial contextual cues can be used to guide movements.

Interaction between color and orientation in the perception of visual variance

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Various characteristics of the external world can be efficiently grasped through summary statistics. Among these statistics, variance is an index of the information of diversity or reliability, and it is useful for making good decisions. In our previous research (Ueda et al. 2020), we found that when using the lines which randomly varied the orientation and length, the perceived variance of the attended feature was systemically biased towards the variance of the ignored feature. In this study, we explored the interaction between color and orientation in variance perception to determine if the systematic bias could be generalized. Each display consisted of 5x5 ellipses with varying colors and orientations. Participants were instructed to focus their attention on either the orientation or color of the ellipses and to determine which of the two successive sets of stimuli had a larger variance for the attended feature. Our findings replicate the previous study that the perceived variance of the attended feature was consistently biased towards the variance of the ignored feature (overestimation and underestimation). However, we observed no bias in variance perception when using stimuli in which color and orientation were separated into different object groups (circles varying in color and gabor patches varying in orientation). Although it has been shown that variance is perceived automatically from unattended items （Ward, et al., 2016; Ducant et al. 2017), the interaction of variance perception between different features may be a process that relatively requires attention.

Acknowledgements: This research was supported by the Japan Society for the Promotion of Science's KAKENHI grant (numbers JP20K20147 and JP15H03462).

Altered resting-state functional connectivity of the cortical central visual field representation in individuals with myopia

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Several studies reported specific alterations of visuospatial attention in individuals with myopia, such as slower orientation to peripheral targets and a narrower, more central attention spotlight. In this study we investigated whether these center-periphery attention differences are reflected in resting-state functional connectivity of the central vs. peripheral visual field representation of the visual cortex.

Sixty adult participants were subdivided into three groups based on a pre-screening questionnaire: 1) corrected myopia (CM) - participants with refractive error of at least -0.5 D, who use corrective lenses most of the awake time, and reported to have good corrected visual acuity; 2) uncorrected myopia (UM) - individuals with refractive error of at least -0.50 D who typically do not use corrective lenses or use additional better lenses for special occasions; 3) emmetropic participants (EM).

Each participant underwent an 8-minute resting-state fMRI session with eyes open. Seed-based functional connectivity between two seed regions (central and peripheral visual field representations of areas V1-V3) and the rest of the brain was calculated for each subject. A one-way ANOVA tested for significant differences in connectivity of these regions between groups.

We found significant differences in the connectivity of the central visual field representation and the sensorimotor cortex. A post-hoc comparison showed higher connectivity in the CM compared to EM group, with an intermediate result in UM. Control analyses ruled out the effects of corrective lens type (glasses or contact lenses) or blurry vision due to insufficient correction as alternative explanations. No significant differences were observed in the connectivity of the peripheral visual field representation.

Our results show increased functional connectivity of the central visual field representation with the sensorimotor areas in myopia. We speculate that it reflects plasticity in the visual system of myopic individuals, which is caused by their overreliance on central vision during sensorimotor coordination.

Motion-induced SSVEPs without motion processing: large-scale cortical dynamics can interact with moving stimuli to produce SSVEPs

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Steady-state visually evoked potentials (SSVEPs) allow the study of specific neural populations by periodically modulating stimulus properties to which they respond. In the motion perception literature, several studies have modulated motion-related properties such as direction and speed, and observed motion-induced SSVEPs. While these SSVEPs are assumed to be generated by motion-processing units, other factors that might facilitate their generation remain unexplored. Here, we hypothesize that position-dependent large-scale cortical dynamics, such as cortical magnification, could also produce motion-induced SSVEPs independently of motion-processing units. In two EEG experiments, we investigated whether modulating stimulus eccentricity and polar angle can generate SSVEPs when other motion-related properties are constant. In Experiment 1, participants were presented with a dot rotating around a fixation cross for 10 seconds. In one condition the dot started rotating from the same angle, resulting in phase-locked modulation of the polar angle. The starting angle was randomized in the other condition, leading to phase-varied modulation. Despite constant motion-related properties in both conditions, motion-induced SSVEPs were only observed in the phase-locked condition. The same frequencies were at noise levels in the phase-varied condition. In Experiment 2, we used the same stimulus but slightly shifted the center of the rotation trajectory so that the dot's eccentricity would be modulated during its rotation. The eccentricity modulation was phase-locked in one condition and phase-varied in the other condition. Consistent with Experiment 1, motion-induced SSVEPs were only evident in the phase-locked condition. These results demonstrate that the generation of motion-induced SSVEPs depends not solely on motion-processing units but also on large-scale dynamics of the visual cortex.

Acknowledgments: This work is funded by TÜBİTAK 3501 Career Development Grant (220K038).

Cortical initiation of spontaneous reversals of visual perception

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We have investigated the neural origins of multistable perception to identify the brain regions responsible for initiating spontaneous perceptual reversals. To that end, ten subjects participated in a kinetic depth paradigm to report exogenously or indigenously evoked perception reversal while their whole-brain BOLD activity was recorded (Siemens 3t Prisma, TR 1s, 12000 s per condition). fMRI signals were preprocessed in MNI 152 space and analyzed based on 758 functional parcels, each consisting of 50 to 400 voxels. Preprocessed signals were Hilbert transformed to obtain coherences, centered around the reports, and then compared against the sham events to be converted into z-score. The threshold (of z=2.5) exceeding latency was computed for each parcel, and it was found that parcels exceed the threshold after the report in exogenous reversals. On contrary, there are two waves in indigenous reversals: an early subset of parcels exceeding the threshold before the report and a late subset of parcels after the report. Furthermore, Pearson correlations between the parcels for an early window (-9 to -1 sec relative to reports) showed that correlation profiles

are significantly different between indigenous and exogenous reversals in several regions: a bilateral frontal group (including the bilateral anterior insula and anterior cingulate cortex), a right frontoparietal group (including right inferior frontal gyrus, parietal lobule and temporoparietal junction), and a visual group (including occipital and superior temporal areas). A combination of early correlation profiles with latencies revealed that parcels in these selected regions revealed both early (pre-report) and late (post-report) threshold exceedings. Further investigations also revealed preliminary evidence that the reversals might have been started by the cooperation of bilateral frontal and right frontoparietal groups and completed by the cooperation of the right frontoparietal and visual groups.

Entrainment of perceptually relevant brain oscillations in visual contour integration: Evidence from tACS and Audio-Visual Entrainment

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This study aims to investigate the role of theta and beta oscillations in visual contour integration. Two experiments were conducted, one using transcranial Alternating Current Stimulation (tACS) to the parietal region (n = 24), and the other using audio-visual entrainment (n = 24), to elicit specific brainwave patterns during contour integration. Both techniques aimed to enhance neural synchronisation, with tACS injecting alternating current, and audio-visual entrainment eliciting repeated neural activation.

During the experiments, participants were asked to detect C-shaped snakes made of Gabors embedded in a field of distractors, and entrainment effects were compared within participants in the 18 Hz (beta), 7 Hz (theta), and sham conditions. To maximise the entrainment effect, a pre-stimulus train of synchronised sound and peripheral flashes was used. For tACS, conditions were separated and counterbalanced in blocks, and the stimulation lasted for the duration of the whole block. The study design and hypotheses were pre-registered (https://osf.io/x8d9s/; DOI: 10.17605/OSF.IO/X8D9S).

The results showed that audio-visual entrainment did not have a significant impact on performance, while beta tACS improved performance compared to theta tACS and sham. A phase effect for entrainment in the theta range was also observed. The findings are consistent with previous research that argues that beta entrainment increases segmentation between target and distractors (Battaglini et al., 2020), while theta entrainment modulates connectivity between lower-order occipital and higher-order parietal brain regions, modulating the deployment of attention (Stonkus et al., 2016). Furthermore, tACS, but not audio-visual entrainment, successfully modulated performance.

In conclusion, this study provides evidence that beta oscillatory patterns play a role in visual contour integration, and suggests that audio-visual and tACS entrainments are subject to different constraints. The study was funded by the Cariparo Foundation in 2022.

Predictive processing in the cortical network of biological motion perception

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While the cortical network that supports biological motion perception is well-established and includes occipitotemporal, parietal, and frontal regions, it remains unknown how it is affected by expectations. In light of the influential models of predictive processing in visual perception, it is time to re-evaluate the feedforward models of biological motion perception that usually ignore the effect of expectations. To this end, in the present study, participants (N=15) went under fMRI while they were shown two point-light displays (in noise) on two sides of the screen. One of the displays depicted a biological motion stimulus (walking or kicking) whereas the other was its scrambled version. The task of the participants was to indicate the location of the biological motion. Before the task screen, they were shown a cue of an action (either walking or kicking) and informed that the cue correctly predicts the action of the biological motion in the task screen 75% of the time (congruent) and violates the prediction 25% of the time (incongruent). There were also two additional conditions in which the cue was uninformative about the action of the biological motion stimulus or there were no motion stimuli after the cue at all. MVPA on the fMRI data showed that pSTS, hippocampus, premotor cortex, and middle frontal gyrus discriminated between the congruent and the incongruent conditions successfully. On the other hand, superior parietal regions and middle frontal gyrus discriminated between the conditions when the cue was informative vs. uninformative. As expected, the discrimination between the conditions in which the (informative) cue was followed by motion stimuli vs. nothing revealed the biological motion network including occipitotemporal, parietal, and premotor cortices. In sum, our results suggest that the interplay between the biological motion network and the regions associated with

memory functions underlie predictive processing in biological motion perception.

Acknowledgment: The project is supported by a TUBITAK grant no 119K654 awarded to B.A.U.

Statistical learning of view-invariance and order-of-appearance revealed by cortical representation of synthetic objects

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Our environment is rich in spatio-temporal regularities and animals learn to recognize and utilize these features, both implicitly and explicitly. Here, we studied neural correlates underlying implicit visual learning of such statistical regularities in scale of single object (~3 seconds) and higher-order temporal context (~30 seconds). For this purpose 8 observers took part in 6 MR scanning sessions while performing an object-recognition learning task. Task consisted of two sets of fifteen recurring and 360 non-recurring objects presented over 3 sessions. One set was presented with a strong predictive temporal context (temporal community-structures) while the other set lacked such temporal dependencies (random).

Multivoxel pattern evoked by each presentation was used to study the view-invariant representation of the object, in the form of object identity representation, by applying a direct discriminant analysis method and decoding the identity of the recurring objects. To study the representation of the higher-order regularities, representational similarity analysis was used to compare the similarity of the patterns elicited by objects within versus between communities.

We show that identity of the synthetic objects are decodable in both ventral (V1 to occipito-temporal network) and dorsal (V1 to parieto-frontal network) visual pathways. Higher-order regularities, on the other hand, are prominent in occipito-temporal regions mainly overlapping with 'identity-selective' regions. Additionally, we observe evidence of presence of a map-like representation, sensitive to boundaries, in insular and orbito-frontal regions distinguishing the objects within but not between temporal communities.

In summary, we exhibit presence of both individual object identity and higher-order temporal context representations, pointing to development of multi-scale abstract forms in ventral occipito-temporal region.

This study is funded by the federal state Saxony-Anhalt and the European Structural and Investment Funds (ESF, 2014-2020), project number ZS/2016/08/80645.

Anatomy of complex perceptual decision making processes in humans

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Maintaining an accurate internal model of our changing environment is essential for efficient decision-making. Previous studies of perceptual decision making were focusing almost exclusively on overly simplistic situations, in which observed changes could be accounted for by a single parameter of the internal model. We extended these investigations to more realistic situations when changes in external conditions could be explained by multiple, equally feasible variants of the complex internal model through the adjustment of its multiple parameters simultaneously. Using Bayesian ideal observer analysis and a novel behavioral 2AFC visual discrimination paradigm, we developed a method in which we could use observers' response biases to identify the internal representations they used during decision making. We found by computational modelling and verified by a set of experiments that in such complex tasks, observers' interpretation was strongly modulated by the specific dynamics of the sequential input. We showed that this behavior could be qualitatively captured by assuming that observers rely on hierarchical representations with detailed dynamics of each parameter of their internal model and use this information for readjusting their model to properly account for the changes in the input sequence. To verify that our Bayesian model fits were correct, we used a strong form of cross-validation: First, we demonstrated that the parameters of the abstract Bayesian model naturally map to the parameters of a process-level sequential sampling model, then we showed that this process-level model could in turn explain idiosyncratic reaction-time patterns present in the behavioral data that were out of the scope of the original Bayesian model. Importantly, our results are compatible with a fully Bayesian view of perceptual decision making, in which uncertainty at various levels of the complex internal model representing and interpreting the external input is optimally accounted for. Our approach provides a new way of investigating human complex decision making.

Neural activation in visual processing regions was related to improvement in the misestimation of body size

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People with eating disorders cannot estimate their body size accurately. Healthy people sometimes show this misestimation and it is a risk factor for eating disorders, thus, reducing misestimation would contribute to preventing developing symptoms. Recent studies reported avoiding negative descriptions while looking at one's body in a mirror (mirror exposure) or imagining one's body (imagery) reduces body dissatisfaction, which would also be effective for misestimation. However, their effects on the misestimation of body size and neural mechanisms of their effects remained unclear. Thus, we examined two interventions' (i.e., mirror exposure vs. imagery) effects on the misestimation and neural responses related to the decrease in misestimation. Twenty-eight young female participants were equally assigned to two intervention groups. The degree of misestimation of body size and neural activation during estimating one's body size were examined before and after interventions. 40 min interventions were conducted once, and the acute effects were examined; change in misestimation and neural responses correlated with its change. We hypothesized the effect of avoiding negative descriptions would be observed in both groups, while the effect of exposure or imagery would be group-specifically observed in each group. The average of behavioral data showed no significant common or group-specific decrease in misestimation. Whereas, individual analysis brain imaging data showed the decrease in misestimation positively correlated with activations in the left superior parietal lobule and bilateral occipital gyri in both groups. There was an imagery-group-specific positive correlation between the decrease in misestimation and activation in the right cuneus. We could not observe robust interventions' effects on the misestimation of body size. However, changes of neural responses were observed in participants who showed a decrease in misestimation. In particular, imagery intervention showed a specific effect during estimating one's body size.

Imaginary scenes are represented in cortical alpha activity

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Our ability to evoke mental images of natural scenes enriches our lives by giving shape to the worlds in our favorite novels or by enabling us to successfully navigate through the environment. How do our brains generate mental images in the absence of visual input? Recent research suggests that cortical alpha activity carries information about individual objects during visual imagery. However, it remains unclear if more complex imagined contents such as rich natural scenes are similarly represented in alpha activity. Here, we answer this question by decoding the contents of imagined scenes from rhythmic cortical activity patterns. In an EEG experiment participants imagined natural scenes based on detailed written descriptions, which conveyed four complementary scene properties: spatial expanse, naturalness, clutter level and luminance. By conducting classification analyses on EEG power patterns across neural frequencies, we were able to decode both individual imagined scenes as well as the scenes' properties from the alpha frequency band, showing that also the contents of complex visual images are represented in alpha rhythms. An additional cross-classification analysis between alpha power patterns during the imagery task and during a perception task, in which participants were presented images of scenes that aligned with the scene descriptions, showed that scene representations in the alpha frequency band are shared between imagery and late stages of perception. In sum, this indicates that the contents of imagined scenes are represented in the alpha band, suggesting that alpha activity mediates the top-down activation of scene-related perceptual contents during visual imagery.

Abnormal networks connections to early visual cortex in posterior cortical atrophy

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Introduction:

The Fronto-Parietal network (FPN) and Default Mode Network (DMN) are two networks shown to play a crucial role in human cognition. These networks differ in their connectivity to V1 by eccentricity: While regions associated with the FPN are most strongly connected with central sectors, regions associated with the default mode are most strongly connected with far-peripheral sectors. Posterior Cortical Atrophy (PCA) is a Neurological disorder including decline primarily in visual function and atrophy of posterior cortical areas.

Methods:

Resting state fMRI and T1 anatomical scans were collected from Eleven PCA patients and 17 age-matched healthy volunteers. For each subject the average cortical thickness in anatomically defined V1 was calculated. DMN and FPN were defined using regions of interest from Yeo (2011) and differences between the networks in the different groups were evaluated at the whole brain level and specifically in V1.

Results:

Cortical thickness in primary visual regions was found to be lower in patients than in controls. Connectivity patterns within the DMN and the FPN were similar between the groups, although differences were found in regions beyond the networks. Focusing on V1, in the control group we received the expected pattern of a distributed connectivity along eccentricity, with

fovea regions showing stronger connectivity to the FPN and periphery regions showing stronger connectivity to the DMN. However, in PCA patients we could not identify a clear difference in connectivity along the eccentricities. ROI analysis of regions from the two eccentricities found a significant effect of network and interaction of location and network in control group, but no significant effects in patient group.

Conclusion:

Lost specialization of function along the Calcarine in PCA patients, may have further implications on large scale networks or vice versa. This impairment, distant form the core pathology, might explain patients' visual disabilities.

Increased Gamma Oscillations are Associated with Visual Working Memory Load

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Recent studies have shown that working memory is associated with brain oscillations, especially with parietal gamma and alpha oscillations. Here we explored how the increased working memory load affects gamma oscillations in adults using a shape-color matching task. The test stimulus consisted of 1, 2, or 3 shapes with different colors (4 shapes x 6 colors). The test and the probe stimuli were presented for 500ms, followed by a delay of 1500ms, and then the probe was presented. The probe and the test could be matched or not by randomly changing the color and/or the shape. Participants (N=8) were instructed to memorize the shape and the color of the test and report whether they matched. Responses and reaction times were collected. EEG was recorded during the task, using a wireless headset by Cognionics, at a 500Hz sampling rate, and with 30 dry channels. Time Frequency Power analyses were performed in specific time windows, for 35-70Hz gamma band frequencies.

The behavioral results show a significant decrease in performance with an increase in the number of items that were required to be memorized. The reaction time was significantly increased with increasing difficulty level, suggesting that a higher memory load is needed with an increased number of items.

The Gamma Power, specifically at occipital-parietal sites, like the behavioral results, showed a significant increase with increasing task difficulty in both time windows: 1) the window between the test and the probe stimuli when working memory is maintained and 2) the time window after the probe was presented in the stage of memory retrieval. The gamma power was significantly associated with reaction time; a slower reaction time showed higher gamma power.

The results suggest that the gamma power can be associated with cognitive load and partially with working memory load.

Neural correlates of visual discomfort: insights from magnetoencephalography (MEG)

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Some people experience discomfort in their eyes and head when looking at repeating or complex patterns, particularly those characterised by limited orientations, high spatial frequency and high contrast. One theory is that this visual discomfort occurs when stimuli are markedly different in their spectral characteristics from natural scenes, which show a predominance of low spatial frequencies and a range of orientations. High discomfort stimuli tend to generate a greater cortical response than images of natural scenes, both in BOLD contrast and neural oscillations, particularly in the gamma frequency. In a series of studies, we are exploring whether people who report particularly high visual discomfort to repeating patterns show differences in their neural response and connectively. We report a correlation between visual discomfort to static images and reduced alpha connectivity in the visual cortex (N = 100), using magnetoencephalography (MEG). This is consistent with a model of reduced inhibitory control and heightened excitatory response in the visual cortex in those particularly susceptible to visual discomfort. In an ongoing study, we are comparing the neural response to gratings across a range of spatial frequencies (1.5-12 cycles/deg) in people who report high and low visual discomfort. Our hypothesis is that individuals with high discomfort will show oscillating cortical circuits with a shift in excitation/inhibition balance.

Can we make the brain symmetry-blind?

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Reflectional symmetry is an important cue for perceptual organization and sexual attraction. The brain can process double axis (e.g., vertical + horizontal) reflectional symmetry rapidly and efficiently. Visual symmetry generates an ERP called the Sustained Posterior Negativity (SPN, Makin et al., 2022). Previous work shows that there are no tasks which completely inhibit symmetry detection and abolish the SPN. We attempted to find the limits of this claim with a series of 7 EEG experiments. All experiments used the same symmetrical or asymmetrical dot patterns. When participants attended to regularity in Experiment 1, there was a substantial SPN (-2.42 microvolts). The SPN

was reduced, but still present, when participants discriminated luminance in Experiments 2 and 3 (-0.836 microvolts). The SPN was again reduced, but not abolished, when participants discriminated the aspect ratio of a superimposed cross in Experiment 4 (-0.722 microvolts). The SPN was also generated when the background pattern was potentially disruptive to the primary task in Experiment 5 (-1.358 microvolts) and when participants attended to negative superimposed words in Experiment 6 (-0.75 microvolts). The SPN was reduced substantially, but again not completely abolished, when participants attended to the orientation of a small diagonal line in Experiment 7 (-0.366 microvolts). While task manipulations can turn down symmetry sensitivity, they cannot switch the system off at the wall, and make it completely un-responsive. Permanent readiness to detect reflectional symmetry at centre of the visual field could be an adaptation.

This project was sponsored by ESRC grant ES/S014691/1 awarded in 2019.

Dissociating the role of visual field maps within the occipital place area

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The occipital place area (OPA), is one of three scene-selective regions in the brain, located on the lateral surface of occipital cortex. Multivariate pattern analysis has identified OPA's sensitivity to both high-level (e.g. landmark identify and scene category), and low-level scene properties (e.g. spatial frequencies and degree of rectilinearity). However, most previous fMRI research is based on the response of all voxels within the OPA, averaging over the visual field maps that subdivide it (Silson et al., 2013; 2016). Here, representational similarity analysis (RSA) was calculated separately within subject specific regions of interest (V3a, V3b, V7, LO1, and LO2), including only the nodes that fell within the larger OPA region.

Participants viewed 96 different scenes in a multi-echo fMRI experiment while completing an orthogonal fixation task. To compare the general structure of the representations across ROIs, we first correlated the t-values for all 96 stimuli and computed the pairwise distances (1-correlation) between the resulting RSA matrices. The whole OPA was most similar to LO2 and V3b and most dissimilar to V3a. Across all pairwise comparisons, the greatest dissimilarities were between LO1 and V3a, V3b, and V7. A similar and correlated pattern was found across the ROI receptive field coverage maps. Second, we categorised the stimuli as in Kravitz et al. (2011) based on their distance (near/far), expanse (open/closed), and content (natural/manmade). Crucially, we found different category preferences across ROIs. V3a grouped stimuli only by content. In V3b, we found an interaction between distance and content, as natural and manmade stimuli had opposite effects for near and far scenes. Within LO2, we found a more complex interaction across all category dimensions. Overall, these data reveal differential responses to scenes across visual field map divisions of OPA, suggesting it may not be a homogenous scene-selective region.

One in Four People Do Not Perceive Phosphenes During Transcranial Magnetic Stimulation on the Primary Visual Cortex

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Primary visual cortex transcranial magnetic stimulation (TMS) can evoke visual percepts, known as phosphenes. Hence, TMS studies often rely on phosphenes as a primary visual cortex localization method or as a brain excitability heuristic. However, it is not always possible to evoke phosphenes in humans. This is reflected by the exclusion of participants in TMS studies, due to the failure of reporting the experience of visual percepts. Because of this, TMS studies can often turn out to be underpowered and/or deviate from the initially planned sample size. To the best of our knowledge there is no systematic estimate to date, that can inform TMS studies, as to the expected rates of successful and failed phosphene induction. Therefore, here, we systematically identified studies that used primary visual cortex TMS to evoke phosphenes, with the aim of determining the expected prevalence of successful phosphene induction and, respectively, the anticipated attrition rate. We identified 95 studies that have used primary visual cortex TMS on healthy human participants, which also provided data regarding the success or failure of phosphene induction. Using Bayesian estimation, we calculated the prevalence of phosphenes from data derived by a total sample size of 1939 participants. The model resulted in a posterior probability with a mean of 0.74 (95% Credible Interval = [0.72, 0.76]). This reveals that approximately 74% of participants can perceive phosphenes and, respectively, a 26% attrition rate should be expected. Our findings revealed that one in four healthy participants will most likely fail to perceive phosphenes during primary visual cortex TMS. This estimate can guide future TMS research, since having an expected attrition rate is important for numerous reasons, such as allocating and saving resources, planning and organizing studies as well as study proposals, and having adequate statistical power and meaningful results.

Population receptive field size in human V1, V2 and V3 varies as a function of cortical depth

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The early visual cortex is governed by the well-established organizing principles of retinotopy and cortical magnification. Receptive field (RF) size varies systematically at the macroscopic scale, increasing with eccentricity from fovea to periphery and along the visual hierarchy. However, the mesoscopic organization of RFs is not yet well understood. While neurophysiology studies in rodents and non-human primates have shown that RF size varies across cortical laminae, evidence in humans remains sparse. Here, we capitalized on recent advances in ultra-high-field fMRI to map RF properties in vivo at the submillimeter scale. We used 7 Tesla fMRI and population receptive field (pRF) mapping to measure gradient-echo blood oxygenation level-dependent (BOLD) responses to a drifting bar stimulus in four human participants. Fitting a 2D isotropic Gaussian pRF model to the BOLD time series of each voxel, we estimated the location in visual space and pRF size that best explain visual field selectivity. Given the known variation of pRF size with eccentricity and across visual areas, we constrained our analysis to an isoeccentricity band centered on 2 degrees. We evaluated the fitted pRF sizes in six equivolumetric cortical depth bins in early visual areas V1, V2 and V3. First, addressing the need for validation in laminar fMRI, we confirm that pRF sizes are smallest in V1, followed by V2 and V3, as expected, and replicate previous findings of a U-shaped relation between pRF size and cortical depth in V1 (Fracasso et al, 2016). We then extend these findings by demonstrating an equivalent depth-dependent pattern in V2 and V3, with a preservation of the hierarchical progression of pRF size across cortical depth. Our findings demonstrate the reliability of submillimeter fMRI in identifying RF properties at the scale of cortical laminar circuits, opening the door to studies of the feedforward and feedback mechanisms of spatial vision.

The effect of reduced temporal signal-to-noise ratio and participant motion on a population receptive field analysis

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Functional magnetic resonance imaging (fMRI) is susceptible to participant motion, which can create artifacts in the data and impair overall data quality. This can be a particular problem in the study of certain clinical groups. Stroke survivors, for example, often show involuntary movements such as tremors and chorea post-stroke. For such participants, reducing the scan time of fMRI experiments can help reduce the chance of motion artifacts. However, while there are a number of ways to decrease overall scan time, many of these methods also reduce the temporal signal-to-noise ratio (tSNR) of the data, often in a spatially non-uniform way. Here, we artificially reduce the tSNR of a data set collected on stroke survivors, to assess the effect of reduced data quality on the results of a population receptive field (pRF) analysis. To assess the sensitivity of the pRF parameters to reductions in data quality, we added different levels of noise or simulated subject motion to the MRI data and refit the model. We also report the details of a tool that allows a convenient quantification of tSNR across multiple brain regions, for scans obtained with different methods (and levels) of acquisition acceleration. This can be used as a framework for improving scanning protocols, especially in circumstances where available time in the scanner may be a limiting factor.

Short-burst stimulation design enhances steady-state VEP responses

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Steady-state visual evoked potentials (SSVEPs) are a robust periodical brain response induced by external rhythmic visual stimuli. SSVEPs have been widely used in basic neuroscience research and brain-computer interface applications. The design of visual stimuli can be optimized to improve SSVEP responses by carefully selecting the suitable properties of stimulus. Nevertheless, how stimulus waveforms affect the response remains under-studied.

Here we compared the SSVEP response of 3 types of waveforms (square, sine and triangle wave) with different duty cycles. Across 3 experiments, we had a total of 25 observers gaze at a flickering disk (radius=1.8º) on a CRT monitor modulated

between white (105cd/m2) and black (0.3cd/m2) against a black background (flickering frequency = 3/6/10/15Hz). Each trial lasted 9s and every stimulus condition was repeated 8-15 times for each observer. Signal-to-noise ratios (SNRs) of SSVEPs were computed by processing the averaged EEG signals through fast Fourier transformation.

The results showed that regardless of the type of waveform, the SNRs were higher for stimuli with shorter duty cycle (e.g., square-wave with 10% duty cycle) compared to stimuli with longer duty cycle (e.g., square-wave with 50% duty cycle). Across 3 experiments, we found that square-wave with 10% duty cycle elicited higher SNRs than those with 30%, 40%, and 50% duty cycle (Ps < .05); sine-wave with an exponent of 15 elicited higher SNRs than sine-wave with an exponent of 1 (P < .001); triangle-wave with 20% duty cycle elicited higher SNRs than those with 100% or 80% duty cycle (Ps < .01). Note that the stimulus with lower duty cycle displayed on average the weakest luminance but turned out to induce the strongest response.

Our result suggests that sharper waveforms, or "short-burst stimulation", could elicited stronger SSVEPs. It provided a new perspective on the optimization of stimulus in SSVEP studies and applications.

Changes in Connective Field properties between primary and later visual areas during visual recognition

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The detailed neural mechanisms behind the interactions between primary and later visual areas during visual recognition remain to be determined. One way to do so is by examining the intracortical connections between visual areas. A suitable approach for this is Connective field (CF) modelling which predicts the activity of one brain region (target) based on the activity of a different region (source). Here, we investigate changes in CF properties during a visual recognition task while observers' brain activity was recorded using functional magnetic resonance imaging (fMRI). In the task, participants viewed static images of animals and objects gradually appearing out of dynamic visual noise. Participants indicated the moment they recognized the image with a button-press. CFs for target visual areas LO1 and LO2 were estimated based on the activity of V1 (source). A CF was modelled as a two-dimensional circular symmetric Gaussian, folded to follow the cortical surface. Estimated CF parameters were location (center eccentricity and polar angle) and size (i.e. Gaussian width). Variance explained was calculated to assess CF-model performance.

We found increased CF-model performance after visual recognition, indicating that connectivity from V1 to LO1 and LO2 increased. For further analysis, a minimum variance explained of 0.5 either before or after recognition was used as threshold. After visual recognition, a larger number of voxels in LO1 and LO2 had CFs closer to the fovea and fewer voxels sampled information from the periphery of the visual field (i.e. CF eccentricity > 5 deg). In LO1, the size of CFs located closer to the fovea decreased, while those in the visual periphery increased. These results suggest selective changes in cortical information processing, which might reflect increased feedback as well as selective attention. Our work helps understand how the primary and later visual cortical areas interact during recognition.

Task-dependent switching of the tuning properties of F5 mirror neurons

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Mirror Neurons in macaque premotor cortex are tuned to the observation as well as to the execution of actions. How these different tuning components interact, and how this interaction depends on tasks that require different types of matching between action observation and execution are unclear.

METHODS: Monkeys were trained with two different hand actions. After observing a video of one of the actions, animals had to either imitate the observed action or execute the other one (anti-imitation). The instruction whether the animal had to imitate the action was given by a cue at the beginning of the trial. The responses of 851 neurons in area F5 in premotor cortex were recorded. We developed a new machine-learning method for the analysis of the population data that partitions the variance into parts that depend either on the visual stimulus or the executed action.

RESULTS: We found that the mirror neuron activity is dominated by the necessary motor response, and not by the visual stimulus. Further, we analyzed the neural response to the instruction cue at the beginning of the trial, which informed the monkey of the necessary response strategy. The tuning properties in this interval where different between the two monkeys that were tested.

CONCLUSIONS: Our results show that the population response of mirror neurons is dominated by the planned motor response to the stimulus. The instruction cue indicating whether observed and executed action match elicits a strong population

response. The tuning properties of this response differ between animals.

Acknowledgements:

HFSP RGP0036/2016; BMBF FKZ 01GQ1704, KONSENS-NHE BW Stiftung NEU007/1; DFG GZ: KA 1258/15-1; ERC 2019-SyG-RELEVANCE-856495; SSTeP-KiZ BMG: ZMWI1-2520DAT700, IMPRS-IS

Alpha and theta rhythms support perceptual and attentional sampling in visual performance

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The visual system owns the intrinsic tendency to process information rhythmically, through a timed coordination of perceptual and attentional processes, involving the activity of coexisting oscillatory patterns in the range of alpha (10-12 Hz), and theta (3-7 Hz), respectively. Here, we aimed to clarify whether variations in task requirements, in terms of attentional demands and side of target presentation, have an influence on the occurrence of either perceptual or attentional components in behavioral visual performance, also uncovering possible differences in the sampling mechanisms of the two cerebral hemispheres. To this aim, we densely sampled visuospatial performance in two versions of a visual detection task where the side of target presentation was fixed (Task 1), with participants monitoring one single hemifield, or randomly varying across trials, with participants monitoring both hemifields simultaneously (Task 2). To reveal oscillatory patterns, performance was subsequently analyzed through spectral decomposition. For Task 1, when attentional resources where focused on one hemifield only, the results showed an oscillatory pattern fluctuating at ~10 Hz and ~6-9 Hz, for stimuli presented to the left and the right hemifield, respectively, likely representing a perceptual sampling mechanism with different efficiency within the left and the right hemispheres. For Task 2, when attentional resources were simultaneously deployed to the two hemifields, we observed a ~5 Hz rhythm both for stimuli presented to the left and the right, possibly reflecting an attentional sampling process, equally supported by the two hemispheres. Overall, the results suggest that distinct perceptual and attentional sampling mechanisms operate at different oscillatory frequencies and their prevalence and hemispheric lateralization depends on task requirements.

Is there an optimal stimulation rate for frequency-tagged visual word-selective responses?

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Fast Periodic Visual Stimulation (FPVS) coupled with electroencephalography (EEG) has revealed a robust index of (pre)lexical representation over the left occipito-temporal cortex (Lochy et al., 2015). In this approach, written words are inserted periodically (usually every 5th item) in rapid periodic streams (10Hz base stimulation) of non-words or pseudo-words. Selective responses for words in the EEG frequency domain (at 2Hz and harmonics) provide an objective and highly sensitive measure of visual word recognition without requiring an explicit task.

Here we determine whether there is an optimal stimulation rate for frequency-tagged visual word-selective responses at the group level, and if this rate varies across individuals as a function of reading performance. Written words were periodically embedded at 1Hz in streams of nonwords (i.e., pre-lexical discrimination) or pseudo-words (i.e., lexical discrimination) presented at four stimulation frequencies (4Hz, 6Hz, 10Hz and 20Hz). 41 adult participants were tested both in EEG-FPVS and with a battery of reading tests.

Across all stimulation frequencies but 20 Hz, which was too fast for detecting meaningful responses, significantly higher amplitude of word-selective response were found in pre-lexical than lexical discrimination, replicating previous observations. Amplitude and scalp topography differed according to stimulation rate, with the largest response over the left occipito-temporal cortex found at 4Hz. The amplitude at this frequency was significantly related with reading speed, i.e., the faster a person reads a word, the larger the amplitude of the word-selective response in lexical discrimination over the left occipitotemporal cortex.

These results suggest that optimal frequencies of stimulation as well as lateralization vary with the type of word-selective response. However, for lexical discrimination, 4Hz (i.e., SOA of 250 ms between items) seems to be the most adapted frequency, leading to a stronger left word-selective response that relates to reading performance.

Ensemble perception: Disparities in processing across the visual processing hierarchy

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People can rapidly construct ensemble perception by computing statistical information such as the mean of visual features from a set of objects in a single glance. However, it is unclear if ensemble processing operates uniformly across all feature dimensions in the processing hierarchy. Five experiments were designed to investigate the ensemble processing of different visual features of multiple objects: (1) brightness, (2) size, (3) shape, (4) perceived age of face, and (5) perceived masculinity of face. On each trial, either one object or 16 objects varying along the manipulated feature dimension were presented on the screen for 100 milliseconds, followed by a backward mask. Then, the participants had to adjust the tested feature of an object presented on the screen and reproduce the single object or the mean of the 16 objects. We developed two measures for ensemble perception: ensemble weighting and ensemble z-score. The ensemble weighting shows, in a visualization map, how observers weighted individual objects when calculating their mean, and the ensemble z-score measures the standardized estimation error of the ensemble mean relative to single-object perception. The results revealed significant disparities in the ensemble processing between the lower- (brightness and size) and the higher-level visual features (shape, perceived age, and perceived masculinity): the participants integrated the lower-level features of all displayed objects using similar weightings while reporting a biased mean of the features (underestimating the mean brightness and overestimating the mean size). In contrast, the ensemble perception of the higher-level features is constituted of higher weighting in the center than in the surrounding; in addition, surprisingly, the participants accurately estimated the mean of features. Combined, these results suggest that the ensemble processing differs across the visual processing hierarchy in terms of integration weighting and standardized estimation errors of elements.

Working memory load influences sensorimotor simulation during reading.

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According to the sensorimotor simulation view of language comprehension, the body's perceptual and motor systems ground linguistic meaning. One source of support for this view comes from the sentencepicture verification (SPV) task, in which observers read a sentence that implies—but does not explicitly describe—an object's shape and then must report whether a pictured object was mentioned in the sentence. Participants are typically faster to verify objects mentioned in a sentence when they match the shape implied by that sentence. However, several high-profile studies have failed to replicate this and other key results supporting the sensorimotor simulation view, raising questions about the extent to which language comprehension relies upon modal representations. One explanation for these conflicting findings is that individuals do not obligatorily tap perceptual and motor systems to understand language, but are instead flexible in their use of sensorimotor simulation depending upon contextual factors such as task demands. I investigated this possibility by asking participants to perform the SPV task while concurrently holding either auditory or visual information in working memory. Although I hypothesized that a concurrent visual working memory task would interfere with participants' ability to simulate the visual properties of objects during reading, I found that higher working memory loads in both the auditory and visual domains reduced the SPV match advantage. This finding suggests that sensorimotor simulation is not necessary for language comprehension, but may instead depend upon the availability of working memory resources.

Integrating Mental And Sensorimotor Workspaces

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Humans exhibit remarkably complex cognitive abilities and adaptive behavior in daily life. Cognitive operation in the "mental workspace," such as mentally rotating a piece of luggage to fit into fixed trunk space, helps us maintain and manipulate information on a moment-to-moment basis. Skill acquisition in the "sensorimotor workspace," such as learning a new mapping between the magnitude of new vehicle movement and wheel turn, allows us to adjust our behavior to changing environmental or internal

demands to maintain appropriate motor performance. While this cognitive and sensorimotor synergy is at the root of adaptive behavior in the real world, their interplay has been understudied due to a divide-andconquer approach. We evaluated whether a separate domain-specific or common domain-general operation drives mental and sensorimotor rotational transformations. We observed that training in the visuomotor rotation facilitates mental rotation, particularly by improving the rotation rate but the other motor task without rotation does not. Reversely, we also showed that mental rotation training enhances visuomotor rotation, but other cognitive tasks without a rotation judgment do not. Such bidirectional transfer between two widely different tasks highlights the remarkable reciprocal plasticity and demonstrates a common transformation mechanism between two intertwined workspaces. Our findings urge an explicitly integrated approach to enhance our understanding of the dynamic interdependence between cognitive and sensorimotor mechanisms

Beyond labeling THINGS-IN-3D: Is one visual hierarchy enough?

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Positioned in an environment filled with objects and people, we immediately know what the objects around us are. The computational challenge is to transform the input into discrete labels or a continuous semantic space. But we also know how to move our bodies to interact with those objects. The computational challenge is to transform the input into a continuous space of movements. Can the same visual hierarchy support both tasks? To answer this question, we need to gain a better understanding of the space of behavioral outputs and collect large databases of a broader set of human behavior toward natural objects. As a step towards this goal, we collected THINGS-IN-3D, a database of two different behaviors on a large set of 3D-printed objects: 1) a grasping task and 2) a similarity judgment task. Comparing the two tasks suggests that these two output spaces are largely distinct. We next explored if the features extracted in different layers of deep convolutional neural networks (DNNs) could be useful in deriving both outputs. For similarity judgments, the accuracy of the predictions for similarity judgments increased from low to higher layers of the networks, while those for grasping behavior increased from low to mid-layers and then dropped dramatically at higher layers. These results suggest that for building a system that could perform these two tasks, the hierarchy may need to be split starting at the mid-layers. One visual pathway may not be sufficient for performing both tasks.

Computational modelling of continuous reaching tasks reveals novel relationships between visual target selection and execution of reaching movements

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We recently developed a computational model of reaching towards a visual target in a multi-target environment based on biologically plausible mechanisms, termed CoRLEGO. CoRLEGO's attentional selection of the reach target uses a biased competition mechanism, while the motor system is based on the dynamic neural field theory. Studies with CoRLEGO demonstrate that target selection and movement execution do not have to operate in a serial fashion (i.e., first selection of reach target and then the execution of movement) as commonly assumed in classical theories. Instead, both systems are able to operate successfully in parallel. Critically, CoRLEGO demonstrates that in this processing style the process of target selection leaks into the motor system, i.e., reach trajectories can reflect the process of attentional selection.

In the talk, we will present three successful applications of CoRLEGO. First, we show that the leakage effect can explain the curvature effect from priming of pop-out targets in continuous reaching tasks. Second, when the model is equipped with separate priming mechanisms for target (facilitation) and distractor (inhibition), fits to reaching trajectories indicate that the temporal order - distractor inhibition first and target facilitation later - best describes population level data in line with recent EEG-studies. Finally, fitting CoRLEGO to individual participants indicates that individual participants not only vary in their priming strategy (i.e., temporal order of facilitation and inhibition) but also with respect to how strongly target selection and movement execution are coupled, revealing a novel factor in the interplay between perceptual processing and motor system.

Footprints of visual cortex organization in early object categorization

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We hypothesized that the first categories that infants represent are constrained by the dimensions that organize object representation in the primates' ventral visual cortex, giving rise to the categorical distinctions: animate/inanimate, human/nonhuman, faces/bodies, natural/artificial and big/small objects.

In a series of studies involving 169 infants in total, we analyzed differences in looking times between objects of the above categories.

Results showed that 4- and 6-month-olds' behavior is primarily guided by low-level visual features such as image size; 8-month-olds are sensitive to low-level differences between images but also show spontaneous categorization of objects along the animate/inanimate dimension. Tenmonth- olds categorize objects as animate/inanimate, above and beyond low-level differences between images. More categories emerge between 10 and 19 months.

Moreover, as infants grow and represent more categories, their looking behavior correlates with the object-related neural responses in everlarger portions of the visual ventral stream of adults, measured with fMRI. This suggests that the formation of new categories is promoted by the progressive recruitment and integration of more and more feature spaces distributed over the visual cortex. In another set of studies, EEG frequency-tagging was used to capture an automatic visuoperceptual correlate of the animate/inanimate categorization in a very heterogeneous set of objects. This response was already evidenced in 4-month-olds. Parallel work in adults shows that low-level visual features preserved in phase-scrambled images, and

midlevel visual features preserved in so-called texform images, are sufficient to evoke the above categorical response, speaking in favor of the visual origin of the early animate/inanimate categorization process.

Multivariate assessment of visual category representations in the infant brain from EEG

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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.

Using deep neural networks as a model for the development of human visual categories

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The adult human brain contains very rich, multidimensional representations of objects. It has proven difficult to understand how and why these representations and their properties come about. Luckily, many of these representational properties also emerge in deep artificial neural networks (DNNs) trained in image classification. Here I will illustrate how these DNNs help us understand how some properties of human representations might develop. As an example, I will use the human perception of zoomorphic objects. It is common to find objects that resemble animals on purpose (e.g., toys), and the perception of such objects as animal-like seems obvious to humans. This "Animal bias" for zoomorphic objects has been shown to be absent in DNNs, despite the ability of these networks to categorize animals from objects. Yet, we successfully induced this bias in DNNs trained explicitly with zoomorphic objects. Alternative training schedules, focusing on previously identified differences between the brain and DNNs, failed to cause an Animal bias.

Specifically, we considered explicit training in the superordinate distinction between animate and inanimate classes, the sensitivity for faces and bodies, the bias for shape over texture, and the role of ecologically valid categories. These findings provide computational support that the Animal bias for zoomorphic objects is a unique property of human perception yet can be explained by human learning history during development.

Categorizing scenes based on gist emerges by 18 months

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Human adults are extremely good at identifying the overall meaning of a scene in a single glance - its gist -, such as a park or a beach, even of completely novel images of scenes never encountered before. However, little is known about the development of scene processing and whether young infants encode conceptual information from visual scenes they encounter daily. In the present study, we investigated whether 12- and 18-month-old infants are already extracting and encoding conceptual information from 2 categories of scenes that they might be familiar with:

Mealtime and Playtime. In two eye-tracking studies, we investigated whether infants would look longer at a scene with a novel gist rather than one with the same gist information after exposure to a series of scenes with a common gist. In Experiment1, we first familiarized infants with three different exemplars of a specific scene category. Following familiarization, in each test trial, two novel pictures, one from the same and the other from a novel category, were presented simultaneously on the screen. We found no preference for the novel or familiar scene at test in either age groups.

In Experiment2, we used a similar procedure, except that during

familiarization, a pseudo-word was played for each scene cat gory to test whether language would aid scene-gist extraction, similarly to how it aids object categorization. Our results show that with labels, 18-month-olds, but not 12-month-olds could extract high-level conceptual commonalities and recognized the gist of scenes from the perceptually different but conceptually related scenes.

High-level visual information of local fragments affects object recognition

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Visual inputs to the human brain are extremely rich, originating from about 130 million photoreceptors. Despite this high resolution, little information is necessary for object recognition. For example, a few fragments of an object's outline suffice for its recognition. While the recognition of fragmented objects has been heavily investigated, it is still unknown which type of fragments provide the largest amount of information for object recognition. Past research has either tested mid-level vision fragments, such as curved segments, or only simple dots placed along the object's contours. It remains unclear if the different high-level information provided by different fragments' types has an effect on object recognition. We hypothesize that fragmented objects are better recognized with corner-like fragments similar to the stimuli preferred by V4 neurons compared to dots (keeping low-level image statistics comparable). To test this, we developed a novel object encoding algorithm based on contour extraction and on convolutions between the object's contours and low- as well as mid-level fragments. Twelve human observers identified twenty-five fragmented objects (corner-like segments vs. dots) generated by our algorithm. Not surprisingly, the odds of recognizing objects were greater the more fragments were presented (B=5.44, SE=0.49, $p<0.001$, OR=230.1). In line with our hypothesis, objects fragmented with corner-like fragments were 2.5 times more likely to be correctly recognized compared to objects with dotted outlines (B=0.92, SE=0.4, $p=0.02$, OR=2.5). It suggests that additional local information provided by the mid-level fragments are extracted and used by observers for object recognition. These results are not due to differences in inherent object's recognizability, fragments' size, spatial frequencies or luminance. Our results are important both for basic vision research as well as visual neuroprostheses where the number of electrodes in the retinal or cortical implant is strongly limited.

The Temporal Dynamics of Size Constancy in Natural Scenes

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Accurately perceiving the size of objects is crucial for many real-world behaviors. Accurate size perception relies on size constancy mechanisms, which combine the object's retinal size and distance information to infer the real-world size of the object. It remains unclear, however, when the retinal size and distance information are combined to infer real-world object size. Here, we used a multivariate pattern analysis (MVPA) approach to EEG data (N=31) to decode stimulus information from patterns of neural activity. Participants watched large or small objects presented near or far within natural scenes while performing an unrelated one-back task. The stimuli were always presented with the objects appearing at central fixation. Using linear classification on multi-electrode response patterns, we decoded the retinal size of the objects over time. We compared decoding of objects whose sizes were perceived as relatively similar due to their position in the scene (large-near versus small-far objects), to decoding of objects that were perceived to differ more in size (large-far versus small-near). When the scenes reduced the perceived size difference between objects, decoding accuracy (large versus small retinal size) decreased after 240 msec from stimulus onset. To ensure that this reduction in decoding accuracy indeed reflects a change in object size perception (rather than a difference in stimulus-separability that is unrelated to size), we next trained classifiers on large and small objects presented without a scene, and tested these classifiers on objects presented within the scenes. We found that early representations of object size retrieved from isolated objects (<200 msec, reflecting retinal size) transferred better to size representations of differently perceived objects compared to similarly perceived objects within scenes, starting from 200 msec after scene onset. Together, these results reveal the time course of size constancy, showing when object representations are modulated by distance information extracted from natural scenes.

Is peripheral object discrimination relying on visual imagery?

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According to the foveal feedback hypothesis, shape information presented in the visual periphery can be processed by the foveal cortex. The foveal cortex is thought to function as a high-resolution spatial sketchpad, a type of visual working memory. Previous research has demonstrated that presenting a central mask between 100-300 ms after target onset impairs discriminability, suggesting that foveal contribution is

disrupted. The purpose of this study was to investigate the relationship between foveal feedback and visual imagery. Participants (N=53) had to perform a same/different task on two diagonally opposing peripheral stimuli. A mask could be presented foveally at different SOAs between 0 and 400 ms. Every participant compiled two questionnaires on visual imagery (OSVQ, VVIQ). We used the discriminability index (d') as a measure of performance in the same/different task. We correlated questionnaires' score with: a) the performance when the mask was not present (baseline); b) the performance when the mask was presented at 100 ms; c) the amplitude of the dip in performance, expressed as the difference between the minimum d' and the baseline d'; d) the timing of the dip in d'. Contrary to prediction, mask disruption was not restricted to SOAs ranging from 100-300 ms and was maximal when the mask co-occurred with the stimulus. There was high individual variability in terms of timing and amplitude of the dip, but no significant correlation between the score in the questionnaires and the characteristics of the dip. Therefore, the link between mental imagery and foveal feedback was not confirmed. These results suggest that foveal feedback is a more complex mechanism than hypothesised in the literature, and that individual differences play an important role in its employment when discriminating peripheral stimuli.

The study was funded by the Cariparo Foundation in 2022.

The probabilistic nature of coding episodic memories

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To generate efficient behavior, probabilistic theories of perception propose to link internal representations and the incoming sensory input based on the subjective uncertainty the observer has about them. Episodic memories, that is episodes experienced earlier by the observer, are a significant part of the internal representations, yet it is unknown whether they are encoded with their uncertainty and if so, what governs the uncertainty of an episode. To address this issue, we conducted four memory experiments on the encoding of episodic events, in which participants (N = 95) viewed a set of individually or concurrently presented oriented objects and later they had to recall these objects and their orientation and provide their subjective certainty about the orientation. The orientation of the objects in separate experiments was sampled from a uniform or Gaussian (bumped) distribution or in a condition when two of the three objects in each scene had identical orientation (glued). Calibratedness, the correlation between accuracy of the orientation and subjective (un)certainty was used to detect probabilistic coding. Recall of individually or concurrently presented objects with uniform orientation distribution confirmed that observers' coding of these episodes was highly calibrated. The "glued" results showed significantly different overall accuracy between glued and unglued objects with nonsignificant correlation within a scene. Since correlations in accuracy between the two glued objects within a scene were significant, the overall advantage of glued objects had to originate from attention being drawn to the glued structure rather than better memory of certain scenes. Bumped results showed higher overall accuracy but reduced calibratedness indicating an effect of the learned meta-structure: both certain and uncertain guesses utilized the bump information. These results support the idea that, similarly to incoming sensory information, episodic memory is treated probabilistically in perceptual processes and that this process relies on both within-scene and across-scene structures.

Spontaneously emerging structural constraints and top-down expectations jointly determine representational efficiency in a predictive coding network

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Sensory neurons in early retinotopic cortex are tuned to basic stimulus characteristics such as local orientation. Neurons tuned to cardinal orientations are over-represented in V1 and have narrower tuning functions than those tuned to other orientations. This non-homogeneous distribution of orientation preference manifests behaviourally in characteristic biases and greater sensitivity to over-represented orientations. Recent theoretical accounts conceptualise this aspect of the early visual system as a structural constraint on information processing, embodying a global, context-independent prediction: that the visual environment is enriched in features with horizontal and vertical, rather than oblique orientations. Here, we studied three aspects of such predictive structural constraints: (i) their emergence in a neurobiologically plausible neural network; (ii) how they contribute to the representational efficiency of the network; and (iii) their interaction with a more familiar form of prediction, namely, context-specific expectations, which influence visual processing via top-down modulation. We implemented a bi-directional convolutional predictive coding network, which we trained to reconstruct images of natural scenes. In line with previous studies, we found that units with orientation-tuned receptive fields developed in a V1-like layer of our network. Critically, non-homogeneities emerged spontaneously: the network developed a greater preponderance of receptive fields with cardinal as opposed to oblique preferred orientations. This emergent structural constraint endowed our network with greater representational efficiency (sparser neuronal activation patterns) with respect to natural images relative to a network with a more homogeneous receptive field distribution. A similar effect on representational efficiency was

achieved by context-specific top-down expectations; moreover, predictive constraints and expectations interacted in a non-linear fashion. Together, our network model highlights the differing but complementary roles played by these two forms of prediction in achieving representational efficiency and flexibility, and informs novel hypotheses about further structural constraints in the sensory systems of living organisms.

Feature synergy is based on regional saliency during figure-ground segregation

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Recently, we reported that a low-level summary statistic, net contrast energy, calculated from multiple scales and orientations, predicts summation of orientation and spatial frequency cues in the detection of bandwidth modulated textures. Here, we generalize this finding and predict cue summation for detecting spatial frequency and orientation feature modulated textures with the same local energy model, using a signal detection theory framework. The common modeling base for both texture generation principles points to enhancement of figure-ground segregation as the crucial factor behind the psychophysical cue summation effect in detection tasks. Since target texture detection may involve shape processing at earlier or later stages on the processing hierarchy, we compared texture cue summation in detection and in a complex shape identification task, testing subtle shape discriminations beyond figure-ground segregation. In each task we adjusted d' sensitivity for orientation or spatial frequency modulated textures to the same levels. Contrary to earlier results reported for simpler shape discriminations, we found a weaker double-cue advantage in the complex shape identification task. Double-cue sensitivity was notably lower than the algebraic sum of the single-cue sensitivities, a level which was reached in the detection task. Measurements with high target-background feature differences showed perfect detection performance, both with single cues and their combination. Shape identification accuracy, however, saturated between 83% - 90%, indicating that enhanced target salience is insufficient for extracting unique shape representations from the texture stimuli. The combined findings corroborate that cue summation enhances figure-ground segregation, while there is no evidence that it also augments more specific processes involved in the recognition of shape from texture. These results suggest that the feature synergy effect rests on local energy-based processing at early retinotopic sites, a conjecture, which is currently investigated with EEG source localization techniques.

Are visual processing tendencies associated with a difference in Body Image Concern?

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Patients suffering from anorexia nervosa process visual info mation differently than non-pathological people. For example, they show a diminished size-weight illusion and there are indications that they perceive food size and shape differently. As multiple factors determine the development of an eating disorder, abnormalities in visual perception could be a fundamental factor in body image concerns and subsequent severe somatic diseases. We tested people with different not yet clinically relevant levels of Body Image Concerns (BIC). The results of previous studies about changes in visual processing are mixed, for instance it was revealed that people with higher BIC levels showed a local visual processing bias, newer studies showed the contrary.

In the present study, we will investigate correlations between global and local visual perception tendencies and different levels of BIC in a systematic way . We will follow a two-step approach. First, BIC levels will be broadly assessed via an online survey in a large representative sample. Next, we will select a smaller participant sample to include a maximally broad and even set of BIC values. The selected participants will undergo multiple tests measuring their visual processing tendencies, concentrating especially on global and local processing. This study aims to produce critical indications for therapeutic interventions as well as possible preventions and screening measurements for eating disorders.

Using the Natural Scenes Dataset to identify brain regions responsive to the colour statistics of objects in natural scenes

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It has been proposed that the colour properties of objects and backgrounds differ, and that the probability that a given colour is 'from' an object rather than the background is a useful cue for object vision and recognition (Rosenthal et al., 2018, JOV, 18(11), 1). In support of this, macaque inferior temporal cortex is more responsive to colours which are more frequently associated with objects than backgrounds (Rosenthal et al, 2018). However, the colour statistics of objects and backgrounds have only been quantified using one image database which might

be biased. Which human brain regions are responsive to the colour statistics of objects when viewed in natural scenes is also unclear. Here we address both needs by analysing the Natural Scenes Dataset (Allen et al., 2022, Nat. Neuro., 25(1), 116-126), a 7T fMRI dataset in which eight participants viewed up to 10,000 unique natural scenes over multiple scans. First, we analysed the chromaticities of pixels from backgrounds and 80 segmented common objects shown in their typical contexts. We found that object pixels were warmer, redder (L/(L+M)), more saturated and darker (L+M) than the background. Second, pixels were categorised into 240 colour 'bins', and the probability that pixels were from objects was calculated (object-colour probability). An average object-colour probability for each image was calculated based on the colour of the object pixels (high score indicates image has typically coloured objects). We then correlated the average object-colour probability of each image with the BOLD response. Our preliminary results suggest, in agreement with the findings of Rosenthal et al (2018) for macaques, that the human ventral visual pathway is responsive to the colour statistics of objects in natural scenes.

Acknowledgements:

The work was funded by ERC grant 772193 COLOURMIND to AF and ERC grant 949242 COLOURCODE to JB.

Task-independent allocentric representation of symmetry using polygons

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Visual symmetry activates regions in the extrastriate cortex and generates an ERP component called the Sustained Posterior Negativity (SPN). The extrastriate symmetry network can overcome visual distortions that destroy regularity in the image and achieve an allocentric representation of symmetry. A previous study has shown that these allocentric representations are only constructed when symmetry is task relevant (Makin et al., 2015). However, it is possible that some stimulus types facilitate allocentric representations during secondary tasks. To test this, we compared SPN responses to symmetrical configurations of Gabors and solid polygons. Stimuli were either presented in the frontoparallel plane or with perspective distortion. There were 3 groups of 40 participants. The first group performed a regularity discrimination task, the second group performed a luminance discrimination task and the third performed a sound-luminance congruency task. We observed an SPN response for Gabors and solid polygons in all 3 tasks. In all tasks the SPN was larger for the frontoparallel stimuli than perspective stimuli. This perspective cost was reduced by solid polygons, compared to Gabors. We conclude that some level of allocentric representation occurs in all tasks and with different stimuli, however, there is no case where perspective cost is reduced to zero. This suggests that conditions for view invariance are more subtle than suggested by Makin et al. (2015). Future work will examine SPN magnitude in rich scenes with different cues to facilitate automatic allocentric representations.

Individual Differences in Internal Models Determine Scene Perception

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How does our brain make sense of the complex inputs it receives during everyday vision? Widely applied predictive processing theories suggest that visual inputs are compared to internal models of the world. On this view, effective visual perception is thought to occur when these inputs align well with our internal models. However, the specific contents of these internal models in individual people are not yet well understood. To explore individual differences in internal models, we conducted a drawing study that enabled participants to provide unconstrained descriptions of their internal models for different natural scenes. Specifically, participants were asked to draw typical versions of scenes (e.g., a typical kitchen or living room). On the group level, the composition of these drawings was well described by the occurrence frequency of objects in a large set of natural scene photographs, as well as by the objects' conceptual distance to the scene category in a distributional semantics model. Notably, individual drawings varied substantially between people. Our key hypothesis was that these variations capture individual differences in internal models that are capable of predicting differences in perception. To test this hypothesis, we constructed controlled 3d-rendered scenes from the drawings and asked participants to categorize them under brief presentation times. Across two studies, we found that participants were more accurate at categorizing scenes that were similar to their own drawings, compared to other people's drawings, supporting the idea that individual differences in internal models can affect scene perception. Overall, our findings shed new light on why visual perception differs across participants. Our methods further provide a new impulse for the development of a truly personalized approach to visual perception.

The effect of natural scene statistics in static and dynamic synthetic images on perceived restoration and shape discrimination

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Natural scenes are not only overwhelmingly visually preferred to urban setting but viewing natural environments has been linked to improved performance in tasks recruiting cognitive resources, even when the viewing experience is indirect (e.g. via screen). We use static and dynamic synthetic images to investigate the extent to which these effects are attributable to image low-level statistical properties.

Experimental stimuli exhibited carefully controlled low-level image properties: either intermediate statistics approximating natural scenes (alpha = 1.25), or statistics departing the 'natural' range (alpha-SPATIAL= 0.50, 2.00; TEMPORAL= 0.75, 2.25). These images were rated on how calm-excited or relaxed-tense they appeared (Study 1), and they also served as irrelevant distractors in a basic shape discrimination task (Study 2). In both studies separate groups of participants rated and were exposed to static and dynamic synthetic stimuli.

Results show that static and dynamic synthetic stimuli with shallower spatial and temporal 1/f slopes were rated as less calming and less relaxing than stimuli with steeper spatial and temporal 1/f amplitude spectra. In the shape discrimination tasks, performance was significantly faster when the shapes matched ($p < .001$, $\eta^2 = .027$). However, performance did not differ between the spectral slopes of the distractor stimuli (all $p > .05$). In addition, despite significantly reduced visual preference for stimuli with shallow spatiotemporal spectra ($p < .001$, η^2-spatial= .30; η^2-dynamic= .60), performance did not differ based on participants' visual preferences (all $p > .05$).

Our findings indicate that despite measurable effects of variations in 1/f amplitude spectra in static and dynamic synthetic images on perceived calmness and relaxation, these image statistics did not influence performance in a shape discrimination task. Future research will benefit from examining whether static and dynamic images with varying image statistics influence physiological markers (e.g. HR, GSR) or measures of stress.

AI versus CG, AI generated convincing materials in different shapes

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The fast development of deep learning models and Artificial Intelligent (AI) tools such as DALL·E -2 and Stable Diffusion unlocked more possibilities for content generation. Traditionally, material rendering in computer graphics domain requires knowledge of 3D modelling, material properties, light settings, etc. However, with the help of AI tools, people now can generate images of convincing materials with just text prompts, which made content creation much easier.

In the current study, we used Stable Diffusion and ControlNet to generate materials in different shapes. We used text to image module of Stable Diffusion, a generative neural network; and controlNet, a neural network structure to control pretrained large diffusion models to support additional input conditions such as outline and depth. We generated 3 different shapes and used the depth model within controlNet to control the shape of objects in the output images, in combination with a stable diffusion text to image model. We used short prompts such as 'a black fabric object' to generate images.

In total, we had 3 shapes, 32 different materials for each shape. 20 participants judged each shape. The procedure is as following: we present stimuli in triplets and ask participants to select the most similar pair in terms of material. Ordinal embedding was then used to analyze data to construct a perceptual space without a great number of trials.

For all three spaces, a 2D space was sufficient to explain the observers' judgements, and they

correlate highly, r=0.95, 0.87 and 0.91. Furthermore, all three spaces have high correlation coefficient with the 2D space from MERL BRDF database, r=0.91, 0.94 and 0.90. Results are consistent and robust, indicating shape did not affect material generation and perception. High correlation with MERL BRDF database space indicates that AI tools can generate materials that are similar to traditionally computer rendered materials.

Influence of curvature and visual context on the perception of artificial human skin appearance

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Reproducing the appearance of human skin by using artificial materials is complicated . The realness of artificial skin is determined by various factors such as color, texture, and shape; however, the role played by each factor in determining the realistic

appearance of the skin has not been investigated in a specific manner. This study investigated the influence of skin shape and visual context on the perception of skin realness. The participant's task in the experiment was to observe a piece of artificial silicone skin sheet at reading distance and rate the level of authenticity. The degree of surface curvature of the silicone skin was systematically manipulated. In addition, the amount of stimulus area that was visible was controlled with a circular window; the edges of the stimulus were occluded with a circular window in one condition, while the stimulus was fully disclosed in another . The results showed that the effects of the curvature and window were significant, i.e., the realness of the silicone skin increased when the surface was moderately curved and stimulus edges were occluded. These findings clarify the importance of shape and visual context for the perception of artificial skin realness.

Animal, plant or mineral: disentangling object concepts from visual features

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Recent studies have attempted to disentangle how the brain processes visual features from semantic knowledge. Many of these approaches employ some form of visual "scrambling" that renders objects unrecognisable. Here, we use images of real but unfamiliar animals, plants, and minerals from Schmidt et al. (2017) to investigate how perception of objects occurs in the absence of knowledge about their true category. We recorded brain activity with Electroencephalography (EEG) while participants actively classified the ambiguous stimuli as animals, plants and minerals, and during a fixation monitoring task. Our results indicate that participants were largely naive of the true classes, and liberally classified objects as minerals but were more conservative for animals and plants. Despite poor classification performance, the true class of the stimulus was distinguishable from multivariate patterns of neural activity in both the classification and fixation monitoring tasks. However, compared to the true class, representations in the brain more closely matched behavioural classifications of the stimuli. Overall, our findings demonstrate that even without top-down knowledge of an object's 'true category', the brain encodes both the 'true category' based primarily on mid-level shape features, as well as the expected category.

Cardinal repulsion biases of real-world objects in three dimensions

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When participants recall the orientation of simple 2D stimuli such as tilted gratings, their report often exaggerates the deviation that an orientation has relative to vertical or horizontal, known as "cardinal repulsion bias". Previous work suggests that this effect is directly tied to increased sensitivity for cardinal orientations – the so-called "oblique effect". In turn, this increased sensitivity is thought to stem from adaptive changes by the visual system in response to a natural world where vertical and horizontal occur more frequently than other 2D orientations (e.g., Girschik, Landy & Simoncelli 2011; Wei & Stocker 2015). Here we ask if people also show increased sensitivity and/or repulsion biases relative to meaningful 3D axes. We briefly (0.5s) present participants (N=10) with a three-dimensional sample stimulus (a cat) that is always sitting upright, thus projecting a vertically oriented image to participants. However, the angle of the cat is pseudo-randomized around the yaw-axis, such that the cat may be facing left (90º), right (270º), towards (0º) or away (180º) from the observer, or any angle in between (0°–359°). After a 0.8s delay, participants rotate a probe cat to match the angle of the sample cat. Participants showed lowest errors at, and repulsion away from, "yaw-cardinals" (0°, 90°, 180°, and 270°). This implies that axes in this dimension provide meaningful context that is used by participants when recalling yaw-rotation angle. This finding cannot be explained by increased sensitivity to cardinals in 2D, as the cat's 2D vertical orientation remained constant throughout. However, it remains possible that 3D objects in the natural world are more often seen from a "yaw-cardinal" viewpoint compared to other angles, resulting in increased sensitivity for yaw-cardinals. In sum, our results show a generalization of known distortions in 2D orientation recall, to more complex 3D stimuli.

Out of sight: The Impact of Hidden Objects on Visual Search in 3D Scenes.

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Virtual reality (VR) has opened up a vast array of possibilities for studying visual search. Despite the new opportunities it offers, past research has largely overlooked the potential of interaction with the virtual environment during search. Target objects were always positioned in visible locations and very rarely hidden. In reality, however, objects frequently appear inside others, such as yogurt in a fridge. We created interactive virtual environments to mimic a quasi-natural visual search situation. Fifty-six unique target objects were placed in 28 3D-modelled indoor rooms. Target objects were placed either at visible or hidden locations. Object placement was further conditioned on

the objects' "degree of constraint" (i.e., likelihood to appear in multiple locations in scenes or being anchored to a specific object), such as a monitor to a desk. The experiment consisted of two blocks: a search phase, and a repeated search phase (as a memory probe). Our findings revealed longer search durations, and interaction counts when targets were hidden. Moreover, constrained placements resulted in shorter search durations even for hidden objects highlighting the importance of scene grammar in guiding visual search. Looking for hidden objects, participants prioritized scanning visible areas of a room before considering the likelihood of an object being hidden to avoid missing potentially "low hanging fruit". During the repeated search phase, scanning times were reduced for hidden objects, and verification times were reduced for visible objects. This suggests that participants relied more on scene memory rather than object memory. Overall, finding a hidden object was more demanding and required an interactive exploration of the environment. Therefore, we argue that future studies on visual search need to include hidden objects to become more ecologically valid. With this experiment, we contribute to a broader understanding of how VR can move visual search experiments closer to the real world.

Do changes in the ability to perceive shape from shading index cognitive function? Evidence for sex-specific effects.

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Young, Western observers typically assume light originates from an above-left location in shaded stimuli in which a light source is not explicitly depicted. This left bias is thought to reflect hemispheric asymmetry. Like certain cognitive functions, behavioural markers of hemispheric asymmetry reduce with age and are often sex-specific, yet the relationship between cognitive function, sex, and hemispheric asymmetry have not been reviewed. This study assesses the relative contributions of age, sex, and cognitive function on performance in two typically left-biased behavioural tasks: the Honeycomb measure of the assumed light direction and the Landmark Task. Sixty-seven older adults (41 women) aged 60-87 years judged whether geometric shapes, shaded to convey 3-D depth, were convex or concave. The stimulus was rotated across 24 orientations (ranging from 0° to 330° in 15° increments), and the proportion of convex judgements to each orientation was used to generate an estimate of their assumed light direction. We also assessed whether participants' responses to the Honeycomb stimuli were significantly modulated by the orientation of the stimulus, providing a measure of sensitivity to shading information and categorised them as sensitive or insensitive to shape-from-shading. Cognitive function was assessed using the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005). Though men exhibited a more leftward bias than women, this difference was not significant. Interestingly, women who were insensitive to the stimulus had significantly lower MoCA scores than women who were sensitive; however, there was no difference in cognitive function between sensitive and insensitive men. The results of this study suggest that age-related changes in the cognitive processes associated with resolving 3-D depth from shaded stimuli are sex-specific.

Untangling the contributions of conceptual similarity and scene entropy in the success of meaning maps

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The cognitive guidance theory of visual attention states that viewers allocate visual attention to the parts of the scene that are expected to be most informative. The expected information of a scene region is coded in the semantic distribution of that scene. Meaning maps have been proposed to capture the spatial distribution of local scene semantics to test cognitive guidance theories of attention. There are at least two possible explanations for the success of meaning maps in predicting visual attention. First, meaning maps might measure scene semantics. Second, meaning maps might measure scene features, overlapping with, but distinct from, scene semantics. We disentangled these two sources of information by considering both conceptual information and non-semantic scene entropy simultaneously. The conceptual information of a scene was operationalised as its semantic similarity map, and scene entropy as its Shannon entropy map. We assessed how well these two maps captured eye-movements of 21 participants freely viewing the scenes for 3s each. Additionally, we conducted a commonality analysis to extract unique and shared sources of variance. We found that scene entropy accounted for more unique variance in the success of meaning maps than conceptual information. Although meaning maps may index some aspect of semantic information, their success thus seems to be better explained by non-semantic information. Note, however, that both semantic and non-semantic information were captured by meaning maps and that some explained variance was not explained by either source of information. We conclude that meaning maps may not be a good tool for testing cognitive guidance theories of attention, since they capture only a small portion of semantic information. As it stands, the semantic information contained in meaning maps seems too ambiguous to draw strong conclusions about how and when semantic information guides visual attention. Implications for the semantic guidance theory are considered.

Semantic Contrast: Quantifying the Change in Semantic Content Across Images

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Visual information in the environment is typically continuous over time, allowing observers to accumulate knowledge of unfolding events. Breaking this continuity elicits changes in eye movements, but the factors influencing these changes are poorly understood. Here, we propose that they may be driven by the degree to which the semantic content of the visual input changes. To test this hypothesis, we developed a method to quantify the change in semantic content across two images (i.e., the 'semantic contrast') and applied it to analyse eye tracking data. In our experiment, 48 participants freely viewed 80 sequences of images from films (i.e., 'frames'). Each sequence included several frames that showed a consistent unfolding of events, followed by a frame that was unrelated to them. We labelled the objects in the last two frames and, for each sequence separately, we calculated the semantic contrast between them. To do this, we used a computational linguistic tool (GloVe; Pennington et al., 2014) to estimate the pairwise semantic dissimilarity of objects across the two frames and then averaged the obtained values. This resulted in a score representing the overall semantic contrast between the two frames. We found that increasing semantic contrast between the last two frames in the sequences — indicative of a greater change in the semantic content — resulted in decreases in the average number of fixations ($p = .044$) and saccade length ($p < .001$), and an increase in average fixation duration ($p = .007$). We propose that this pattern of eye movements may reflect changes in focussed attention proportional to the processing difficulty elicited by changes in semantic content. As such, we demonstrate the applicability of our method in capturing the degree to which semantic content changes across time, and how this change in semantic contrast results in characteristic eye movements.

This research was funded by the Leverhulme Trust (RPG-2020-024).

Towards Fairly Evaluating Object Detection Performance in Humans and Machines

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Evaluating the similarities and differences between computer vision systems and human observers is an increasingly important subfield of vision science. However, quantitative comparisons between human and machine vision are often hindered by the different evaluation techniques used in these separate fields. In computer vision, task performance is often measured by a system's accuracy in predicting the identity and location of a set of predefined ground truth labels. By contrast, human performance on visual tasks is typically measured through psychophysical experimentation, often involving repeated 2AFC responses. Given these distinct metrics, performing fair quantitative comparisons of models and humans is non-trivial, especially for complex tasks like object detection. To address this, and more fairly compare humans to computer vision models, we design a psychophysics experiment measuring human performance in an object detection task similar to those used in computer vision, and then simulate a psychophysics experiment in an object detection model, directly comparing performance. We study this in the context of peripheral vision, comparing the ability of humans and machines to perform tasks with the limited information available when viewing objects in the periphery. For the human experiment, we evaluate human subjects' performance in a 2IFC object present/absent task, viewing images from the MS-COCO dataset containing objects at a range of eccentricities. We then test the performance of computer vision models trained for object detection on the same present/absent images, transformed with the Texture Tiling Model to simulate peripheral viewing. Finally, taking inspiration from signal detection theory, we simulate a psychophysics experiment for object detection models. We do this by using model label prediction probabilities for present/absent image pairs to calculate d' for an ideal observer, sampling from the resulting distribution to simulate 2AFC responses. Comparing humans and machines on the same benchmark, we show that humans out-perform object detection models at object detection tasks in peripheral vision, identifying methods of improving computer vision performance on peripheral vision tasks.

A flower in a vase and a plant in a pot: The visual representation of spatial relations

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Recent research suggests that visual perception represents objects as well as high-level relations that bind objects in meaningful structures. We studied the visual perception of containment and support, using frequency-tagging EEG. Building on the view that perceptual processes are fast and automatic, we reasoned that if a given relation (e.g., support: one object on another) is visually encoded just like other visual properties of a scene, we should find a distinctive response in the EEG signal, whenever that relation is seen. Moreover, if this response reflects relation perception, it should be found regardless of the specific objects that implement the relation (vase on table, pillow on couch, hat on head and so on).

Fifteen human adults saw different images of a relational category (support: spoon on cup, chalk on mug) at a periodic rate of 2.5 Hz (base-frequency). Images from another relational category (e.g., containment: spoon in cup, chalk in mug) were inserted every 4th image (oddball frequency: 0.625 Hz). If relational categories are automatically encoded (and discriminated) upon visual stimulation, a second response should be found at the oddball frequency. We found responses to image presentation (2.5 Hz) over occipito-parietal electrodes, but no significant responses to changes in the relational category (0.625 Hz). Hence, we found no evidence that the visual system computes high-level relations such as support and containment, independently from the objects that instantiate those relations. Further (ongoing) experiments investigate the hypothesis that perceptual representations of relations are tolerant to variations within object categories but not between object categories : on this hypothesis, the EEG response to a given relation (e.g., containment with spoon A in cup A) would generalize to other instances of spoon in a cup (e.g., spoon B in cup B), but not to containment events involving other object categories (e.g., fish in a bowl).

Spatial-frequency channels for object recognition by neural networks are twice as wide as those of humans. An explanation for shape bias?

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We compare how well human observers and neural networks recognize ImageNet images in filtered noise using the critical-band masking paradigm (Fletcher, 1940). We assess the spatial-frequency tuning of object recognition by measuring its noise tolerance at various frequencies (Solomon & Pelli, 1994). 16 observers and 10 neural networks performed 16-way categorization of 1050 ImageNet images perturbed by band-limited Gaussian noise of five strengths centered at seven octave-spaced spatial frequencies. The noise sensitivity of object recognition is an U-shaped function of spatial frequency. We find that human observer performance is severely impaired over a narrow, 1.5-octave-wide "channel" whereas networks fail over a twice-as-wide, 3-octave range, demonstrating that networks use some image frequencies that humans do not. When recognizing objects, networks are known to rely on texture cues whereas humans rely on shape (Geirhos et al., 2019). We observe that the bandwidth and center frequency of network channels correlate strongly with their shape-bias scores. More shape-biased networks have narrower channels, with bandwidth closer to that of the human channel. We also find that networks with high shape bias have lower channel center frequencies, further away from that of the human channel. Therefore, our results show that perhaps the popular notion of texture-vs-shape bias simply reflects properties of the spatial-frequency channel.

Symmetry Detection in Images of Natural Scenes by Humans and Machines

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Although mirror symmetry is an established and popular principle of perceptual organization, human symmetry detection in images of natural scenes remains highly understudied, when compared to symmetry detection in artificially created dot patterns and shapes. In this multidisciplinary project, we investigate human symmetry detection in 100 images of natural scenes in relation to quantitative metrics derived from computer vision and machine learning. In our study participants were asked to place a rectangular bounding box around an image region they perceived as mirror-symmetric and to indicate the axis of symmetry. They could place as many bounding boxes as they saw fit. For each of them, they also rated the perceived saliency of the region (i.e., how much it popped-out from the background) and the strength of the symmetry (i.e., from rather imperfect to almost perfect symmetry). Statistical analysis of 2173 symmetries by 17 participants so far reveals that participants selected bigger, more salient regions of symmetry first. Vertical axes were much more frequent (around 75%) than horizontal and oblique ones. Horizontally and vertically symmetric regions were found to be more salient and more symmetric than oblique ones. Saliency and strength ratings were moderately correlated (around 0.4) across all regions and images. We used different metrics for image quality assessment to compute symmetry accuracy scores for the bounding boxes, revealing large discrepancies between human and computational symmetry assessment (correlations below 0.1), both for saliency and strength. This emphasizes the need to go

beyond traditional computer vision algorithms and employ deep learning models. Human data collection is still ongoing, and we also plan to train a deep learning model on symmetry detection and present it alongside these findings. Open data and methods: https://osf.io/9tf4e/

Acknowledgment: This work is funded by an ERC Advanced Grant (No. 101053925) awarded to JW.

LangMark – object annotations for scenes with semantic inconsistencies to connect language models to vision science

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Objects in our environment usually appear in predictable arrangements and contexts. For example, tractors, but not octopuses, are typically encountered in farmyards. The human visual system leverages knowledge about these regularities to encode visual information effectively. This process is typically studied using images depicting environments that contain unusual, 'inconsistent' objects (e.g. a farmyard with an octopus in it). A promising novel method of analysing the results of experiments with such images, and experiments with images in general, involves harnessing vector space models of language. These models are based on large corpora of texts and capture relationships between words. For example, these models can determine if the words 'cup' and 'fork' are more related to each other than 'lamp' and 'shelf'. If applied to the names of objects in images, these models allow for quantifying abstract, high-level image content with unprecedented precision and flexibility. One obstacle to the widespread adoption of these models is that they require images in which all objects are annotated (outlined and named). To facilitate the uptake of language models as tools for vision science, we created LangMark: publicly available object annotations for 124 scenes with inconsistent objects. One half of the scenes belong to a widely used SCEGRAM image set, and the other half has been selected from a predecessor of SCEGRAM. Each scene has different variants: the inconsistent object is either present, replaced with a consistent (typical) object, or absent and not replaced. To demonstrate the utility of these annotations, we show that a langue model, GloVe, correctly distinguishes between the consistent and inconsistent objects within the scenes and allows for quantifying the degree of object-context inconsistency in a data-driven way. Overall, LangMark is a resource that will be useful in contexts ranging from cognitive psychology experiments to creating computational models of high-level scene perception.

Funding: Leverhulme Trust grant (RPG-2020-024) to IM, PB, and AC and BA/Leverhulme Small Research Grant (SRG22\220332) to MP.

Investigating the Emotional Responses and Preferences of Individuals to AI-Generated visual stimuli

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The use of Artificial Intelligence (AI) in generating various types of human-like outputs has sparked interest and debate over the past 12 months. One of the most discussed abilities of recently released AI is the one of being able to produce images. However, despite the growing prevalence of AI-generated artworks over the internet and various groups of interest in the technology, there is still much that remains unknown about how humans perceive these stimuli, and how individual differences can influence their perception. As such, the aim of this study was to investigate how personality and individual attitudes can modulate the way individuals perceive AI-generated images.

We conducted an online experiment in which participants were presented with a series of images that were generated by an AI algorithm or made by humans. Participants were then asked to rate the images on various psychological dimensions, including how emotionally pleasant they found the images, and how much they liked the images. Preliminary results from this study will be discussed, attempting to shed light on how humans perceive and interact with AI-generated visual stimuli. Our findings have potential implications for the design and implementation of AI-generated images. Specifically, our study has the potential to highlight the importance of considering individual differences when a new technology has to gain support and become acceptable. Furthermore, can be translated into knowledge regarding other types of AI technologies, as well as stimulating future research in the area. Finally, the study has the potential to highlight the need for further cognitive and psychological research in the area of AI-human interaction, as we continue to explore the capabilities and limitations of this technology.

To investigate the influence of body perception and body satisfaction on eating attitudes

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The eating attitude can be affected by Body Image Distortion, which includes the distorted perception of body shape and body dissatisfaction, leading to negative emotional experiences. Previous studies have often used self-report to measure body satisfaction but lacked objective measures of individuals' perception of their own body shape. Therefore, our study developed the Image Marking Procedure (IMP) to measure the distorted perception of body shape. Then we investigated the impact of distorted perception and body dissatisfaction on eating attitudes. Participants completed the IMP, Body Shape Questionnaire (BSQ-34), and Eating Attitudes Test-26 (EAT-26). IMP is a projective test in which participants are tagged with labels on the following body parts: right/left shoulder, right/left waist curves, and greater trochanters of the right/left hip. Participants remained in a standing position in front of a white wall and projected the point. The evaluated measurements were the distances between the points marked by the perceived size (PS) and by the actual size (AS). Body Perception Index (BPI) was calculated based on these values using the following formula: BPI = PS/AS x 100(%). A higher score for BPI indicates that perceived size differs more from actual size. A higher score on BSQ-34 indicates higher body dissatisfaction. A higher score on the EAT-26 represents more severe eating attitudes and behavioral problems. We conducted correlation analysis on all measurements, and the results showed a positive correlation between the BPI and EAT-26, and a positive correlation between the BSQ-34 and EAT-26. The findings suggested that individuals with a distorted perception of their body shape and higher levels of body dissatisfaction tended to exhibit more abnormal eating attitudes and behaviors. The IMP can objectively measure the distortion in body shape perception.

Online food choices: When does “recommended by” work?

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Recommendations, for example, by "the chef" help increase healthier and/or more sustainable food choices. However, little is known about whether recommendations are still effective when choices are limited, as is typically the case in university cafés. More importantly, it is unclear how factors such as price interact with the recommended choice or menu. To test this, participants (N = 512) in a smartphone-based online study were visually presented with two menus (Dahl or Curry) from which they had to choose one, with either none recommended or one of two (none, Dahl or Curry). Additionally, we manipulated the price of the menus (high or low) and the position of the menus (top or bottom). Participants were then randomly assigned to one of the resulting 12 factor-level combinations (for example, the recommended expensive Curry menu at the top, the cheap Dahl menu at the bottom). The subsequent analysis (probit with post-hoc ANOVA) with recommendation, price and position as independent variables and menu choice as dependent variable showed more or less only effects regarding the choice of the more popular menu, the Curry (chosen on average with 66%). Specifically, only when the Curry menu was presented at the top did a differential effect of recommendation emerge. That is, when the Curry was the expensive option, the recommendation had a negative effect on its choice (43% chose it), but not when the Curry was the cheap option (87%). To conclude, only if, for example, university cafés know whether a menu is popular might manipulations such as position or recommendation be useful in further promoting a particular menu choice.

Influence of context on facial expression perception in an at-risk sample of children with emotional difficulties

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Many neurodevelopmental psychopathologies are characterised by emotion perception difficulties which are typically evaluated with isolated facial expressions. However, it is well-established that context substantially influences facial expression perception in the typical population. For instance, when faces are shown in the context of a body, the perception of facial expressions in both adults and children is biased towards the emotion of the body posture. Critically, the magnitude of this bias is determined by individual differences in the precision of facial expression representations, with more precise representations leading to less influence of body posture. In the current study, we assessed whether similar principles for the integration of facial and bodily emotion cues apply to children, who are at-risk of developing psychiatric conditions. 124 children (aged 4 to 8) from the Cardiff University Neurodevelopment Assessment Unit (NDAU) were included in the study. These children did not meet the criteria for a psychiatric diagnosis at the time of testing, but they represent a unique at-risk sample with emotional, cognitive and/or behavioural difficulties. Children's ability to discriminate isolated facial expressions, isolated body postures and facial expressions in the context of an expressive body was assessed as part of a larger battery of cognitive and emotional tasks. As expected, children’s isolated facial expression and isolated body posture perception were impaired. Moreover, they showed a strong influence of body posture when making judgments about facial expressions. Importantly, however, individual differences in isolated facial expression perception performance drove the extent of bias towards body

posture. This finding suggests that despite impaired isolated facial expression and isolated body posture perception, the integration of face and body signals of emotion in children, who are at-risk of developing psychiatric conditions, follows the same principles as typically developing children.

Impact of morality on the attentional blink

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It has been proposed that humans can automatically identify others' morality and quickly detect liars and cheaters. This study used an attentional blink phenomenon and whether the morality associated with a face can be processed under limited attentional resources. Participants successively conducted an imagination task and a rapid serial visual presentation (RSVP) task. In the imagination task, we presented faces and sentences describing moral violations, moral compliances, or non-moral but emotionally neutral episodes. The participants imagined that the person with the presented face was conducting the acts described in the text. In the RSVP task that followed, the several images including one or two facial images were rapidly and sequentially presented. The participants identified the first face type (T1) and reported whether a second face (T2) was presented or not. The results showed that detecting T2 faces associated with moral violation acts was more accurate under limited attentional resources than detecting T2 faces associated with neutral acts. On the other hand, detecting T2 faces associated with moral compliance acts was less accurate than detecting T2 faces associated with neutral acts. These findings suggest that the morality of a face can be identified even under limited attentional resources.

Seeing Trouble: Relationship between Sensitivity and Threat in response to Ambiguous Emotional Expressions

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People with social anxiety (SA) and autism spectrum (AS) process emotional expressions differently, and these differences might emerge in early visual processing. The current study examines how threat perception influences the perceptual sensitivity to different emotional expressions at different intensities. It also investigates the differences that might emerge in the processing of static vs dynamically changing expressions. Participants' levels of SA and AS are measured. They are then exposed to the 6 basic emotional expressions: anger, disgust, fear, happiness, sadness, and surprise. In the first task, they are asked to indicate whether they experience an emotional expression as threatening or not, and are then measured for their sensitivity to those expressions. The participants first respond to static faces, followed by dynamic, while their eye gaze is recorded. Threat perception and visual sensitivity is measured using the highly sensitive and adaptive staircase method of psychophysics, which has not yet been applied to this field.

Both SA and AS are hypothesized to be associated with greater threat perception of anger and disgust. Perceptual sensitivity is expected to be predicted by perceptions of threat, to a greater degree in SA than AS. Moreover, lower fixations and fixation durations on eye regions are expected, with hyper-vigilance and avoidance of eyes in SA. Threat would play a moderating role between eye movements and SA, but not AS.

Understanding visual sensitivity to threatening emotions may hold the key to understanding transdiagnostic social communication difficulties, not only in static and moving faces, but also real-life facial emotional expressions. The study, and the innovative method, has implications not only on face perception, but also motion and general visual perception.

A model of the interference caused by the presence of others: the role of others' intention.

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How do we cope with others' presence when we have to focus on a specific task? This is a common situation in everyday life that involves social cognition processes. One way to study these processes is using the Dot Perspective Task (DPT), where participants have to judge how many targets are visible from their own or another's perspective. Previous research has proposed two opposite interpretations of how others' presence interferes with our focus: through implicit mentalising processes that allow us to fast and unconsciously process others' visual perspectives; and through sub-mentalizing processes that involve involuntary attentional orienting based on directional features of others (such as gaze direction or body posture). However, these interpretations have limitations and inconsistencies that need to be addressed. In this paper, we propose a new model that explains this interference by combining both interpretations into two fast involuntary processes: an automatic attentional orienting process driven by the directional features of others; and a spontaneous mentalizing process of attribution of intentionality driven by the social relevance of others. Our model also includes a voluntary decisional response selection process that modulates the interference depending on task demands and involves working memory resources. We

show how our model accounts for previous findings and provides a comprehensive framework for understanding this phenomenon. This presentation focuses on the voluntary decisional process, while the involuntary processes are outlined in the companion presentation.

A model of the interference caused by the presence others

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We cannot help but be conditioned by the presence of others. Even when they are not actively engaging with us, the mere view of others interferes with our focus and ability to complete tasks.

This interference has been previously attributed to either a submentalizing or to a mentalizing process. We present here a new model that grew out from the combination of these two interpretations. The model comprises two involuntary processes: an automatic process sensitive to the directional features of others and a spontaneous process of attribution of intentionality sensitive to the social relevance of others. In addition, the model includes a voluntary decisional process which modulates the interference and is affected by Working Memory.

This presentation focusses on the involuntary processes and shows how inconsistencies in literature can be accounted for by this model.

Is imagination necessary for emotional engagement with verbal storytelling?

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Recent evidence suggesting that visualization is an 'emotional amplifier' has several potentially important implications, including improved treatment of PTSD (by decreasing the vividness of imagery of intrusive thoughts) and better decision making (increasing the vividness of imagery of a delayed reward). To assess how essential imagination is for engagement with verbal storytelling, we are recruiting participants with various degrees of vividness of mental imagery, and measuring their degree of emotional engagement while hearing or seeing emotionally charged excerpts from a novel. Participants were rated for vividness of imagery using the Vividness of Mental Imagery Questionnaire (modified VVIQ; Marks, 1973). Aphantasia is the inability to generate mental images, which is operationally defined as a low VVIQ score (16-23 out of a maximum of 80, Zeman et al. 2020). Hyperphantasia is the ability to generate extremely vivid mental images, operationally defined as having a high score (75-80). Participants were recruited from the general population on Prolific, and from self-identified aphantasics and hyperphantasics on Reddit. Our stimuli included 6 different emotionally charged excerpts from novels (in the format of audiobook), and 6 equivalent scenes from the movie and tv adaptations. Each participant experienced an audio block and a visual block in random order. Each block consisted of 3 snippets in random order. The Narrative Engagement Questionnaire assessed the level of emotional engagement (Busselle and Bilandzic, 2009). We have results from 6 of a planned 24 participants. Finding a positive (or zero) correlation between vividness of mental imagery and narrative emotional engagement would indicate that imagination is (or is not) necessary for emotional engagement with verbal storytelling.

Real or fake? The authenticity evaluation of photojournalistic images depends on the viewers' political beliefs.

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Photojournalistic images shape our understanding of the sociopolitical world. When photographic evidence is not easy to be dismissed as fake - and, conversely, not all scenes captured by the camera appear plausible - the question of how and why people form judgments about the truthfulness of the photo becomes crucial. In the current study, we aimed to examine whether people with different political beliefs vary in evaluating the authenticity of the scenes.

We have chosen 1000 contemporary (2014-2021) photojournalistic photographs from the European Press Agency database, depicting a variety of worldly events affecting the lives of people and societies (military conflicts, riots, humanitarian crises, natural disasters, etc.). A representative sample of 300 participants was asked to judge whether they consider each photo real or fake and to declare confidence in this decision (scale 0-50). We assessed their political beliefs (Political Beliefs Questionnaire with the cultural and economic subscales) while controlling for demographic characteristics. Each person viewed a randomly selected subset of 100 images.

A considerable number of scenes - 30% - were judged as fake, despite all of them being authentic to the best knowledge of the authors. Importantly, judgment depended on political beliefs, with right-wing people more often judging scenes as fake. Observed links are especially strong for the economic scale. The certainty of the decision also depends on political beliefs: right-wingers have a tendency to be less certain when they evaluate

scenes as real. Worth noticing, outcomes do not depend on participants' demographic characteristics.

Our results indicate that even a real photojournalistic photograph could be considered fake without any suggestion other than just asking a question; and that this effect varies depending on the viewers' political beliefs. What guides the decision process in the authenticity judgment is worth further exploring.

Different leveraging of contextual visual information during the prediction of social and non-social perceptual events in typical and atypical neurodevelopment.

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Recent findings showed an impairment of children with autism in using the visual information embedded in a context to make prediction about the unfolding of a social event. However, it is unclear whether this impairment is specific for the social domain or also generalizes to non-social events. In the first case, the deficit could be accounted for by the motor deficits present in autism; the second case would prompt to a general atypical pattern of perception in autism. To assess these issues, we tested children with autism (n=31) or with dyspraxia (n=33) as compared to age-matched peers with typical development controls (n=102) in a social (action) and non-social (shape) prediction task. Both tasks consisted of familiarization and testing phases during which participants watched moving hands or shapes and had to predict the movement outcome. The familiarization phase was aimed at implicitly promoting the building of perceptual expectations based on visual contextual cues. During the subsequent testing phase, videos were occluded to reduce the amount of sensorial information and promote the usage of expectations to predict event unfold. While controls' performance benefited from using contextual priors in both tasks, such facilitation was absent in children with autism, either for social or non-social perceptual predictions. Differently, children with dyspraxia showed poor reliance on contextual priors in the social task only. These results provide evidence for a domain independent deficit in autism in using priors to predict events, and for a domain- (social) specific deficit in individuals with deficits limited to motor competence.

Acknowledgements: this research was supported by the Italian Ministry of Health (Ricerca Corrente 2023)

Are social interactions preferentially attended in real-world scenes? Evidence from eye-tracking

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Socially relevant features of complex visual scenes are processed with a higher priority than non-social features. When considering how we direct spatial attention to multiple people in a scene, most studies to date have presented face-to-face versus back-to-back dyads, finding that attention is preferentially drawn to those presented face-to-face. This has been taken as evidence that social interactions capture attention because of their importance in helping us navigate our social world. The stimuli used in these experiments have often consisted of two bodies facing each other at an equal distance against neutral, sparse backgrounds. A limited number of studies have investigated social interaction processing in real world scenes. In this experiment, we presented participants (N= 27) with complex visual scenes containing multiple people. In each scene, there were at least two individuals interacting and at least one other lone individual. The same stimuli were also presented upside down. We tracked participants' eye movements for 5 s whilst they viewed the scenes. If social interactions draw and maintain attention over and above lone individuals in complex scenes, we expected that participants would fixate earlier and would spend more time looking at individuals presented within an interaction than a lone individual. Our findings did not support this hypothesis. Interactions were not fixated significantly earlier, or for longer, than lone individuals. However, we did find an effect of inversion on dwell time, with social aspects of the scene being attended to for longer in upright than inverted images. Our results suggest that in real-world scenes, interacting individuals are not preferentially attended when presented in competition with other social information.

Low aesthetic value ("ugliness") without semantics

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Aesthetic evaluation of images is influenced by perceptual, cognitive and emotional factors (Redies, Spatial Vision, 2008). In particular, the decision to rate an image as "ugly" (low aesthetic value) is strongly influenced by the emotional context. Last year we presented an image database (Parraga et al, ECVP2022) devoid of contextual information termed Semantic-

Content Devoid dataset (SCD) which consisted only of images of natural objects (trees, rocks, dirt, landscapes, etc.). Crucially, this database contained a significant proportion of artificially "uglified" scenes, constructed by asking observers to manipulate image features (contrast, Fourier content, mean brightness, colour, etc.) to lower their aesthetic value. We then used a crowdsourcing paradigm to obtain independent valuations of the whole dataset (1-5 Likert scale, 10426 images, 100 valuations each). In this work we analyse the changes that observers generated to reduce the aesthetic valuation of the images in the absence of strong semantic content. Our results show that in the absence of a strong emotional context, observers manipulated some of the low-level features in two directions, (e.g., increasing or decreasing the average colourfulness, lightness, etc.) and some in only one direction (e.g., decreasing global contrast and image fragmentation or increasing Fourier alpha-slope, etc.). This work was funded by the Spanish Ministry of Science and Innovation projects PID2020-118254RB-I00 and TED2021-132513B-I00.

The effects of art expertise on the relationship between perceived object stability and aesthetic judgments

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The perception of architecture evokes aesthetic impressions as well as stability regarding mechanics. Arnheim (1977) discussed the perception of architecture evokes visual dynamics and they are not only derived from physical behavior on buildings but also from the observer's knowledge and experience. Recent studies which investigated psychological responses to physical behavior caused by the position of the center of mass discussed the relationship between the perceived stability of objects and aesthetic judgments (Samuel & Kerzel, 2013). however, it has remained unclear how people's knowledge and experience reflect in the process of perceived stability and aesthetic judgments.

The objective of this study was to investigate the effects of art expertise on the relationship between perceived object stability and aesthetic judgments toward a self-standing object. Stimuli objects were created in which the object fell over or not with the position of the center of mass.

Eighty university students participated in the experiment, and 76 were included in the analysis. The participants rated self-standing objects with perceived object stability (stable - unstable), beauty (beautiful - not beautiful), and fall estimation (not falling - falling). Conceptual understanding of physics and art expertise were measured by questionnaires. This study was approved by the ethical research committee at the University of Tsukuba. The analysis was conducted using a generalized linear mixed model that considered repeated measures data.

We found that a conceptual understanding of physics leads to different perceived object stability and that art expertise affects aesthetic judgment respectively. On the other hand, a conceptual understanding of physics and art expertise did not affect the object fall estimation. We then discussed the process of perceived object stability and aesthetic judgments are parallel rather than serial cognitive processes. Overall, we experimentally confirmed that the relationship between perceived object stability and aesthetic judgments is changed by art expertise.

The effect of agency on the beauty of images

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What effect does one's sense of agency have on one's beauty judgment of images? Past research shows that emotion affects image beauty, and stimulus duration plays a role in this effect. So what happens if participants, instead of the experimenter, have control over stimulus duration? In this study, participants rated the perceived beauty, happiness, and sadness of 24 art images and 24 nature photographs. The stimuli were presented in two blocks. In the "no-agency block," stimulus duration was 2, 6, or 15 s. In the "agency block," participants controlled duration, from 2 to 15 s. Participants took a mood questionnaire before and after each block, and they viewed a mood induction video between blocks to increase their happiness or sadness. Preliminary results show that, in the agency condition, congruent subject and object emotions interact (|????| ~ 0.07 in a linear mixed-effects model), i.e., subject emotion affects the relationship between object emotion and beauty. However, in the no-agency condition, effects of subject emotion on beauty are negligible. Thus, we find that subject emotion affects image beauty only when participants control duration. This suggests that agency enables emotional engagement which in turn affects beauty.

Exploring preference for symmetry using the method of production

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Symmetry is a major predictor of aesthetic judgments for abstract patterns and we know that even small deviations from symmetry can have strong negative effects. However, it is unlikely that all deviations have the same effect. After all, symmetry is not the only factor determining visual goodness.

We applied the method of production to the study of preference for symmetry. We started with 50 abstract patterns consisting of black elements arranged in an 8x8 grid on a white background, all showing small random deviations from symmetry. The task was to modify the patterns by changing 1 to 3 grid cells. One group of participants (N = 26) was instructed to aesthetically improve the patterns, while another group (N = 20) was instructed to aesthetically impair them. It was forbidden to make the patterns symmetric. In sum, 1246 improved and 984 impaired patterns were created.

For a validation experiment, we selected one improved and one impaired pattern for each of the 50 initial patterns. In each trial, participants (N = 32) saw four patterns: The initial pattern deviating randomly from symmetry, a symmetric, an improved, and an impaired version. The task was to rate and rank the four patterns for liking and interest. We found that impaired patterns were indeed on average less liked and improved patterns more liked than initial patterns, confirming that participants successfully followed instructions. Symmetric patterns were on average most liked, but outranked improved patterns in only 56% of the cases. Furthermore, symmetric patterns were clearly rated less interesting than all other versions.

In sum, we showed that it is possible to create abstract patterns deviating from symmetry that approach fully symmetric patterns in liking, while retaining the higher level of interestingness that can be found in asymmetric patterns.

Effects of Spatial Ability on Complexity Preference in the Aesthetic Appreciation of Chinese Landscape Paintings

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Starting with Birkhoff's (1933) proposal of monotonic inverse relationship between aesthetic preference and the complexity, extensive research has been done in modulating and expanding this equation by taking other factors such as arousal, familiarity, symmetry, and categorical prototypes into account to unscramble the large individual differences in their aesthetic experiences. Here we revisited this issue with an emphasis of the role of the intrinsic capacity in processing visual spatial information. Specifically, we investigated whether and how spatial abilities restrain people in their appreciation of Chinese landscape paintings with high complexity.

We measured the spatial abilities of 40 undergraduate students (50% females; aged range: 19-22 years, no advanced art education) in three aspects: mental rotation, spatial visualization (Embedded Figure Detection), and sense of direction (Roadmap Test). Participants then need to intuitively select one out of two simultaneously presented landscape paintings that they liked more. Complexity of these paintings were estimated with image statistics along three dimensions: Fourier spectrum slope, fractal dimension, and Shannon entropy (see Mather, 2020). To minimize the top-down influence in art appreciation, we restricted the presentation time of all paintings to 500 ms. Participants' preference for complexity along each aforementioned dimension in the art appreciation was derived from the comparisons of their chosen rates between high- and low-complexity paintings.

We found that individuals with higher mental rotation ability showed significant selection bias toward the paintings with higher unpredictability in tonal and color values (i.e., Shannon entropy). However, those with better sense of direction showed selection bias toward the paintings with lower geometric complexity (i.e., fractal dimension). Spatial visualization ability did not affect any complexity preference in our data. The combined results suggest that spatial abilities for object-based and egocentric spatial transformations differ in their influences on the complexity preference in the aesthetic experiences with Chinese landscape paintings.

The automaticity of 'seeing-in': Pictorial depth cues influence judgments of surrounding spatial relationships even when task-irrelevant

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Many representational paintings give a strong impression of depth, despite being flat surfaces which lack any depth—a phenomenon often referred to as 'seeing-in'. It has been claimed that, by attending appropriately to pictorial artworks, we can sometimes perceive them as flat. In contrast, here we report two experiments which show that observers cannot fully "turn off" their perception of depth in a picture. Rather, when viewing a pictorial artwork, impressions of depth arise automatically, and irresistibly interfere with judgments of surrounding spatial relationships, even when the painting is entirely task-irrelevant. In Experiment 1, observers viewed a virtual gallery with two freestanding walls, and reported as quickly as possible which wall was closer to them. Each wall displayed a painting—an abstract artwork featuring a luminance gradient, which, depending on its orientation, looked either convex or concave. On Congruent trials, the near wall displayed a convex-looking painting, and the far wall displayed a concave-looking painting. On Incongruent trials, this was flipped. Although observers were told to ignore the paintings, and to focus only on the wall placements, they were unable to ignore the paintings' pictorial depth cues, and responded slower in the Incongruent condition. Thus,

seeing-into a picture occurs automatically, and interferes with an orthogonal task even when we are trying to ignore the painting. Does this also occur for more complex paintings? In Experiment 2, one of the walls displayed a Renaissance or traditional East-Asian painting, and the other a phase-scrambled version of the painting (abolishing depth cues). Observers responded faster when the original painting (with pictorial depth) hung on the far wall, compared to when it hung on the near wall. We conclude that seeing-in is automatic: even when trying our best to resist seeing depth in a picture, it is not possible to perceive a pictorial artwork as flat.

Objective vs subjective order and complexity in relation to aesthetics tested with evolutionary algorithms

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Gestalt psychology famously stated that “the whole is more/different than the sum of its parts”. This paved the way for the introduction of Gestalt thinking in various fields of psychology, but it also led to a “Gestalt nightmare” in aesthetics, where seemingly no features of interest could be investigated separately. Research on the mid-level features “order” and “complexity” could remediate this issue. While complexity refers to the quantity and variety of elements in an image, order refers to their level and type of organization. However, these concepts are multifaceted and difficult to operationalize and, therefore, different measures of order and complexity exist. In addition, a distinction is made between objective and subjective order and complexity.

In this study, we propose genetic algorithms, employing the laws of natural selection, as an innovative means to measure both objective and subjective order and complexity. For the objective measure, two manipulations are chosen. First, the elements of a grid-like pattern are varied on low-level features (e.g., size, hue…) with a variable mean and variation. Second, the pattern that results from this low-level manipulation (dependent on the number of different values per feature) is repeated over the grid in varying manners (rows/columns, ordered/random…), allowing spontaneous emergence of order.

The parameters are adjusted each generation as a function of the evaluation of participants. In a first experiment, on each trial participants choose the most and least ordered image in a set of five, as a measure of subjective order. The parameters of the chosen images are then crossed and mutated to create a new stimulus set for the next generation. In a second experiment, we repeat this procedure with complexity as the evaluative component. This way, we can investigate the relation between objective and subjective measures. In a third experiment, we relate those findings to aesthetics.

Aesthetic experience in museum vs. laboratory: psychophysiological and behavioral evidence

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The educational tools that museums can provide to accompany people on their visits can be crucial factors in determining the quality of the museum experience. Nowadays museums use more and more digital materials (e.g., virtual tours) to attract visitors, therefore it is worthwhile investigating if digital reproductions of artworks are as effective as museum originals in producing a satisfying aesthetic experience.

In a previous work, we compared the impact of informative texts on the cognitive and emotional experience of naïve visitors in a modern-art museum, through multiple psychophysiological (heart rate, skin conductance, eye movements, pupil diameter) and behavioral parameters (viewing time and questionnaires). Here, we repeat the same paradigm in a laboratory setting, presenting the same paintings on the computer screen. Specifically, our research seeks to uncover the effectiveness of written labels in influencing physical and mental states of observers in non-ecological contexts. Additionally, before/after the exposure to paintings, participants had to evaluate valence and arousal of photographs with positive/neutral/negative contents to test for beneficial carry-over effects of art exposure.

Our results show that original artworks in museums are viewed longer compared to their digital reproductions, even though subjective judgments (e.g., appreciation, interest) seem to be comparable. In both settings, descriptive labels increase viewing time, decrease negative feelings, improve comprehension of the paintings, and produce pupillary dilation, although psychophysiological and behavioral effects are smaller in the artificial context. Overall, these effects may be explained by an increase in arousal, as demonstrated by higher arousal scores of photographs after art exposure.

Our findings provide further insights into the comparison of in-person vs. virtual art experience, suggesting that the contextual environment affects paintings' fruition, although some beneficial effects of informative material can be also acquainted throughout digital media in non-ecological contexts.

Contrast Modulation Effects for Different Flanker Contrasts, Separations, and Eccentricities

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Stimuli presented outside the receptive field of single cells in the primary visual cortex (V1) can produce modulation in their responses. This effect is believed to be mediated by horizontal connections between units in V1 and can be measured psychophysically using the lateral masking paradigm. In this configuration, contrast sensitivity of a target (i.e., a Gabor patch) flanked by collinear elements can be increased (facilitation) or decreased (inhibition), depending on the characteristics of the flankers.

In this study, we characterized contrast sensitivity under conditions of lateral masking while systematically manipulating critical parameters such as eccentricity (fovea vs. periphery), flanker-to-target separation (short vs. large), and varying flanker contrast.

In the fovea, at short separations, results showed that increasing flanker contrast shifted contrast modulation from facilitatory to inhibitory. For large separations, the opposite was found.

In the periphery, at short separations, increasing flanker contrast shifted contrast modulation from no effect to inhibition. For large separations, we observed weak inhibition peaking at intermediate flanker contrast. While data from the fovea supports a previously proposed model of contextual modulation (Zenger 2016), this is not the case for the periphery.

Taken together, our results confirm qualitative differences between foveal and peripheral lateral masking effects and depict complex interactions between elements contributing to flanker modulation. These findings can help better understand the mechanisms of visual contextual modulation and provide the basis for the development of future models of the architecture and functioning of the early visual cortex.

Achromatic Increment and Decrement Contrast Processing Differs Qualitatively

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Previous research has found differences in sensitivity to increments and decrements, which is likely due to the differences between ON and OFF channels. In the current study, we performed two experiments to investigate the difference between suprathreshold achromatic increments (A+) and decrements (A-) using 1.5° square stimuli. In the first experiment, we measured the perceptual scale for A+ contrasts and A- contrasts, separately, using Maximum Likelihood Difference Scaling (MLDS). In the second experiment, we measured forced-choice pedestal discrimination thresholds with the same stimuli on different pedestal conditions and multiple pedestal levels. To relate the two experiments, we use a model in which the pedestal discrimination thresholds are inversely proportional to the derivative of the perceptual scale, with constant, additive Gaussian noise. Both sets of results show large asymmetries between A+ and A-. The perceptual scale of A+ follows a Naka-Rushton curve, while that of A- follows a cubic function. Correspondingly, discrimination thresholds (on suprathreshold pedestals) increase monotonically with A+ pedestal contrast, while the discrimination thresholds first increase with A- pedestal contrasts, then decrease as the pedestal contrast gets higher. Our findings generally agree with Whittle's previous studies (Whittle 1986, 1992) which also found a strong asymmetry between A+ and A-, and a 'crispening effect' near the adapting luminance. This asymmetry limits the psychophysical utility of stimuli that contain the same amount of energy of both polarities, such as gratings and flickers. Our results strongly indicate that perception of decrement contrasts is qualitatively different from perception of increment contrasts.

Supported by NSF Grant BCS-1921771

Two kinds of top-down effects in an edge integration model of lightness

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At ECVP 2022, I presented a neural model of lightness perception based on fixational eye movements, contrast encoding by ON and OFF cells, and a cortical edge integration mechanism. The model explains—with only 1.6% error—the large perceptual dynamic range compression that occurs in the staircase Gelb illusion, and it simultaneously accounts for the existence of a Chevreul illusion in staircase Gelb, perceptual filling in, and fading of stabilized images. Here, I extend this model to account for two types of top-down effects in lightness. I show that the extended model can account in an exact quantitative way for individual differences in appearance matches made with classic disk/annulus stimuli when both types of top-down influence are included. In the full model, sensory responses to incremental and decremental luminance edges are encoded by ON and OFF neurons in early visual pathways that have different contrast polarity-dependent neural gains, consistent with monkey physiology. A contrast gain control mechanism then adjusts the neural gains applied to edges as a function of the contrasts and proximities of other nearly edges. A top-down cortical mechanism further modifies the edge gains based on the observer's interpretation of the edge as either a reflectance edge or an illumination edge. A second top-down cortical mechanism suppresses any display edges that are outside of the observer's spatial window of attention from participating in the lightness computation. At the final processing stage, a cortical edge integration mechanism sums the neural responses to the edges across space to compute lightness. The model accounts for appearance matches made in a series of experiments with disk/annulus displays only if the first top-down effect—edge classification—is assumed to operate before the stage of contrast gain control, while the second top-down effect—

attentional windowing—is assumed to operate at a higher processing level, beyond the contrast gain control stage.

Seeing in the dark: face recognition, reading and visual crowding under scotopic conditions

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In many cases, people can function visually in almost complete darkness. However, high-level vision has not been investigated thoroughly under scotopic conditions, where only rod photoreceptors are active. Under these conditions, acuity is low, and a foveal scotoma spreads for about 1 degree in the center of the visual field. We investigated how these limitations affect performance and eye movements in foveal tasks such as reading and face recognition. We recorded eye movements while testing the speed and accuracy of reading and upright/inverted face matching under photopic and scotopic conditions. We also tested scotopic crowding at different eccentricities since it could limit reading abilities. Compared to photopic conditions, under scotopic conditions participants could read accurately but slower, and they showed a similar pronounced face inversion effect (higher performance for upright than for inverted faces). Surprisingly, despite the foveal scotoma, fixations in both tasks were executed to the same locations as under photopic conditions. When viewing upright faces, participants first fixated on/near the eyes, and during reading, participants fixated on the expected preferred landing positions close to words' centers. However, the duration of fixations was longer under scotopic conditions compared to photopic conditions in both tasks. Scotopic crowding along the eccentric axis was similar to photopic results. We suggest that for reading, the lack of use of peripheral vision could be explained by the crowding experiment results, which showed that scotopic crowding, similarly to photopic crowding, increases with eccentricity. For face recognition, it might be explained by the unharmed holistic nature of face recognition, which uses large receptive fields to achieve global perception. These results suggest that high-level visual tasks, even those that rely on foveal input, are solved in a similar manner under scotopic and photopic conditions.

Adaptation to invisible flicker induces spatial distance compression

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Perceived separation between two objects can be compressed following adaptation to a dynamic spatial pattern. Here we used this aftereffect to investigate whether perceived separation depends on pre-cortical stages of visual processing. It is possible to preferentially adapt lateral geniculate nucleus (LGN) neurons using high temporal frequencies, because the temporal frequency cut-off is ~20Hz higher compared to neurons in the primary visual cortex.

An adaptor consisted of black and white discs arranged on a regular grid in one hemifield (11 degrees of visual angle, disc size 0.5 dva), changing contrast at 3Hz or 60Hz. The adaptor flickering at 60Hz was invisible when fixating at the center of the screen, but occasional fixational eye movements made it appear briefly. Observers pressed a keyboard key to report these intrusions. After adaptation lasting 30 s (3s top-ups), observers saw two pairs of dots on the either side of a central fixation point, and selected the pair with the greater inter-dot separation (the standard separation 2 dva; the test 1.2-2.8 dva).

We found separation compression in the adapted region for both adapting temporal frequencies (~15% compression for the 3Hz, and ~10% for the 60Hz adaptor). The magnitude of the compression following adaptation to the high temporal frequency flicker was not related to brief detection of the adaptor stimulus.

In addition, we found that separation compression following exposure to an array of Gabor patches (drifting at 3Hz or 10Hz) depended on the spatial frequency of the adaptor texture, and was maximal for spatial frequencies lower than 5 cycles/degree (~20%).

The mechanism underlying spatial interval computation is sensitive to adaptation at high temporal and low spatial frequencies. This suggests an important role of LGN neurons, which show similar spatial and temporal tuning, in the encoding of spatial relations.

Acknowledgement: Supported by the Leverhulme Trust.

Transfer of motor and CD gain adaptation in the vicinity of the adaptation target

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Visuomotor learning of saccadic eye movements follows an adaptation field. If the motor gain is adapted to change the

saccadic motor command in response to error, adaptive changes transfer to saccades in the vicinity as a function of their distance from the adaptation target. Recently, it was shown that learning does not only adapt a motor gain but also a visual gain that represents the target on the visual map, as well as a CD gain that estimates the saccade size from corollary discharge (CD). Here we measure the transfer of changes to saccade amplitudes and pre- and trans-saccadic target localizations within a circular window around the adaptation target that stepped inward during saccade execution. Based on the relative saccade and localization changes, we disentangle the underlying adaptation of the visual gain, of the motor gain and of the CD gain including their transfer to different positions within the adaptation field. Results show that the amount of adaptation and the amount of transfer to nearby positions differ between gains. We found most adaptation in the motor gain, less adaptation in the CD gain and little adaptation in the visual gain. Moreover, the motor gain showed stronger adaptation transfer to nearby positions than the CD gain. We conclude that learning of saccadic eye movements operates on different gain field maps for motor and CD-based internal saccade representation. These gain field maps hold different transfer functions of how adaptation affects saccades and internal saccade estimates for nearby targets.

Posture aftereffects – Does the visual system adapt to different representations of posture?

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People tend to live sedentary lifestyles and sit for hours in the same slouched posture and head-forward position. These tendencies are concerning as prolonged postural stress is associated with physical (i.e., musculoskeletal pain) and mental health (i.e., depression) implications. Visual adaptation in body perception is an emerging field that has produced insights into the neural bases of misperception of body size and shape. However, there is little research on the perception of body posture and the potential for visual adaptation. This study aimed to examine whether the perception of body posture is susceptible to visual adaptation by viewing images of bodies with either extremely upright or slouched postures. Participants completed the study on an online platform (Gorilla). Half of the test bodies faced the same direction as the adaptation stimuli (congruent condition) while the other half faced the opposite direction (incongruent condition). In the baseline test phase, participants first established the appearance of 'good' posture by manipulating a succession of body stimuli, viewed in profile, from a randomised starting point to their perceived upright position. In the adaptation phase, participants rated a collection of photos of bodies with either extremely upright or extremely slouched postures on various personality characteristics (e.g., kind or mean). The third phase was a post-adaptation repetition of the first test phase. While participants' perception of good posture was significantly different before vs. after adaptation, congruency of test/adaptation stimuli had no effect, suggesting high-level adaptation. These findings contribute to our knowledge of the processing of posture in the brain, and the way posture is perceived in social context. Our observations have the potential to help in finding effective ways to raise awareness of, prevent or correct poor posture more generally.

Sensorimotor Adaptation while Navigating in Uncertain Virtual Environments

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Human navigation in naturalistic environments requires goal-directed behavior and sensorimotor adaptation. While route planning is necessary to reach a certain target, movement plans need to be dynamically adjusted with respect to changes in the environment, such as the sudden appearance of obstacles. As adjustments are costly, humans try to maximize their reward at each step of a sequence of sensorimotor decisions. However, despite gaze leading action, eye movements are not directly rewarded. Instead, gaze functions as a way to reduce uncertainty about the state of the world. Aiming to address the role of environmental uncertainty in a naturalistic setting, we employed a navigation task in virtual reality. Participants' task was to walk through a virtual museum using the shortest pathway to one of two exit doors (left vs. right). Participants had to avoid a virtual museum guest who suddenly appeared in the scene, randomly blocking either the left or the right path of the museum corridor. By varying the number of locations where the obstacle could appear (two vs. four, near and far), we manipulated the level of environmental uncertainty and expected participants to prioritize the potential obstacle locations in the high uncertainty condition and the navigation targets (exit doors) in the low uncertainty condition. In line with our expectations, initial eye-tracking results show significantly larger fixation proportions for potential obstacle locations when uncertainty is high, and larger fixation proportions for navigation targets when uncertainty is low. In the low uncertainty trials, we also found higher fixation proportions for potential obstacle locations when they were near (i.e., closer to the start) than far (i.e., closer to the target). Our results suggest that, as environmental uncertainty increases, humans increasingly prioritize eye movements to locations that can reduce uncertainty at the expense of eye movements to other task-relevant locations.

Navigating Virtual Worlds: A Graph Theoretical Analysis of Eye Tracking Data Recorded in Virtual Reality to Examine Spatial Navigation

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Orientation and spatial navigation are crucial abilities for everyday life. Especially in recent years, the emergence of virtual reality (VR) headsets, especially in combination with eye tracking functionality, offers new opportunities for spatial navigation research. However, despite the many advantages, performing eye tracking in a virtual environment where participants are free to move around provides new challenges for the eye tracking analysis.

To address these issues, we apply a graph-theoretical analysis approach to investigate the underlying patterns of visual attention during spatial navigation based on the eye tracking data recorded from participants freely exploring two virtual cities for 90-150 min. Specifically, we create graphs by transforming the cleaned and pre-processed eye tracking information into one gaze graph for each participant. Our subsequent graph-theoretical analysis of the data recorded in the first city identifies a subset of houses outstanding in their graph-theoretical properties which we define as gaze-graph-defined landmarks. Furthermore, our findings indicate that the gaze-graph-defined landmarks are preferentially connected with each other in the network.

By applying the same analysis to a new eye tracking data set recorded in a different virtual city with different participants, we are able to replicate our findings, again identifying a subset of interconnected gaze-graph-defined landmarks. Finally, the initial model selection process of the participant's performance in a point-to-building task in the second city suggests a stronger influence of graph-theoretical predictors on the task performance compared to the non-graph related measures like distance between buildings and dwelling time, however, more research will be necessary to adequately determine the relationship between the different predictors and the task performance.

Overall, applying a graph-theoretical analysis approach to eye tracking data offers a novel perspective on general patterns in visual attention during spatial navigation as well as providing a unique angle for spatial navigation research in general.

Toward Automatic Detection of Gaze Events in Natural and Dynamic Viewing

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Introduction

An essential step in eye movement analysis is the quantification of the occurrence of specific scanning events. Manually determining such events in a recording is extremely time-consuming. In the past decades, automatic event detection methods have been developed but these have been largely restricted to stationary conditions. However, many researchers are also interested in the scanning behavior of participants conducting natural, daily-life tasks. This has been accelerated by the development of relatively accurate, commercially available, mobile eye-trackers. These trackers can project gaze on scene-camera footage. Yet, automatically deriving the events from their data is complex. Thus far, only a few automatic event detection methods for natural viewing tasks have been developed, but these all rely on additional devices for deriving all events. Here, we present a new method for event detection during natural viewing that requires only gaze recordings and scene-camera movies to derive head and body motion.

Method

Our Natural Eye-movement Event Detection (NEED) method uses gaze motion and computes head rotation using visual odometry in conjunction with similarity measurement of the scene content in the central visual field (a region around the point-of-gaze). This information was provided as input to a Random Forest classifier to predict the events: gaze fixation, gaze following, gaze pursuit, and gaze shifting.

Results

Our method predicted the events in four tasks with an average score of 85%. Over all tasks combined, NEED's score was 76%, whereas the maximum score of the other methods (using additional signals) was 66%. When using agreement labels rather than those of individual labelers, NEED's performance increased from 76% to 87%.

Conclusion

NEED accurately predicts gaze events made during natural and dynamic viewing. Its classification accuracy depends on the quality of the training labels. Its task dependence is a consequence of certain events occurring more often in one task than the other.

Presence in VR predicts hedonic, but not practical user experience rating in an orthoptic psychomotor learning simulation.

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Orthoptic students have to develop clinical psychomotor skills to diagnose and treat eye movement defects and problems in binocular vision. Computer simulations of patients enable students to experience a wide range of conditions and learn the required diagnostic skills in educationally suitable settings. This study compares user experience in a highly realistic VR simulation with a simplified screen-based educational simulation.

Liverpool University orthoptic students used a custom-designed VR tool and the AAO complex strabismus simulator [1] during a simulation-based teaching session. Subjective ratings for user experience were captured using UEQ-S questionnaire which provides separate measures for pragmatic and hedonic UX [2]. In addition, the modified PQ presence questionnaire was used to measure simulation fidelity [3]. Focus groups were conducted using a structured guide to explore student experiences and for thematic analysis.

We evaluated the experiences of the year two orthoptics students (N = 23). There were no significant differences between the web-based and VR simulation in user experience for the pragmatic quality measure ($p > 0.05$). The VR simulation, however, scored significantly better in hedonic quality and simulation fidelity measures (both $p < 0.005$). The latter two measures are highly correlated.

Orthoptic students positively received the VR experience and viewed it as a valuable, engaging resource to use as a precursor to clinical placement. The environment was immersive, and students could clinically assess, observe, and diagnose a range of concomitant and incomitant deviations using VR to consolidate their knowledge and build clinical confidence in a safe, controlled, and measurable environment. Simulation fidelity is a key contributor to hedonic user experience.

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The effects of depth of field on attention in whilst exploring a virtual environment

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A 3D immersive experience allows the user to choose how they sample their environment. Often the designer of the environment wishes the user to interact and view certain parts of the scene. In this work, we test out a subtle manipulation of visual attention through varying depth of field. Varying depth of field is a cinematic technique that can be implemented in virtual worlds and involves keeping parts of the scene in focus whilst blurring other parts of the scene. We use eye tracking to investigate this technique in a 3D game environment, rendered on a monitor screen. Participants navigated through the environment using keyboard keys and began by freely exploring in the first apart and in the second part were instructed to find a target object. We manipulated whether the frames were rendered all in focus (termed a deep depth of field) or whether a shallow depth of field was applied. We measured where on the screen participants looked. We divided the screen into 3x3 equal sized regions and calculated the proportion of the time participants spent looking in the central region. On average across all trials participants spent 67% of their fixation time on the central area of the screen. This means that they preferred to navigate in such way that they were looking in the direction they were heading in. We found that there was a significant difference when freely exploring the scene – participants spent more time looking in the centre of the screen when a shallow depth of field was applied than with everything in focus. This was no longer the case during the search task. We demonstrate how these techniques might be effective in terms of manipulating attention by keeping user's eyes looking straight ahead when they are freely exploring a virtual environment.

We acknowledge support from the AHRC through StoryFutures and partners Spilt Milk Studios

Investigating obstacle avoidance for real and pictorial obstacles

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We are interested in identifying ways to facilitate natural visuomotor behaviour in virtual environments. Specifically, we explored the types of visual cues that are required for natural hand movements. We compared obstacle avoidance behaviour for real obstacles of four different heights with obstacle avoidance behaviour for closely matched 2D and 3D images of the same obstacles. We also tested how exposure to real obstacles affected motor behaviour in response to subsequently presented pictorial obstacles. In separate experiments for 2D and 3D images, participants were asked to move their hand over the obstacles and touch a target position on the other side while their hand movements were tracked. The experiments had a pre-test post-test design. In the first condition, obstacles were presented as images, in the second as real objects, and in the third the same images as in the first condition were presented, again. We computed the magnitude of the avoidance movement (maximum distance from the obstacles) as an estimate of perceived obstacle height. Unsurprisingly, obstacle avoidance for real objects was more accurate than for pictorial obstacles. However, exposure to the real obstacles significantly improved the accuracy of obstacle avoidance in the post-test when 3D images of the obstacles were used. No such improvement was found for 2D images. In several control experiments, we compared these findings to performances in manual size and distance estimation tasks. The improvement in obstacle avoidance does not seem to be the result of an improvement in size perception but probably was due to establishing the correct position in space of the ground plane on which the pictorial obstacles were placed. The findings suggest that prior exposure to matched real obstacles can improve the accuracy of obstacle avoidance in virtual environments. This is relevant for the design of training simulations where natural movement is critical.

Supported by ESRC grant RG15982-10 to CH.

Head movements influence visual stability across gaze shifts

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Gaze shifts produce a drastic disruption of vision about three times per second. Across each gaze shift the sensorimotor system must remap spatial coordinates in order to maintain visual stability. A gaze shift in natural vision mostly consists of a combined rotation of the eye and the head. A saccade brings the fovea to the desired target, followed - with a slower latency - by a head movement to recenter the eyes. During the head movement, reflexive saccades, moving in opposite direction to the head movement, stabilize vision on the retina. In experiments on saccadic remapping, the head commonly remains immobile. Here, we investigated the role of the head movement for spatial processing in a eye-head gaze shift. Participants wore a head mounted display and were required to perform a 20° gaze shift, consisting of head and eye movements from a fixation point to a target. In a first condition, subjects were free to perform the gaze shift as they preferred. In a second condition, subjects were instructed to first perform a saccade to the target, then move their head and to maintain ocular fixation at the target during the head rotation. We measured visual stability by asking subjects to estimate the position of an object briefly flashed after the gaze shift relative to an object briefly flashed before the gaze shift. In both gaze shift conditions, stimuli were only presented when both, eye and head were at rest. We found an overestimation of space in the condition in which gaze could compensate for the head movement that is constant with previous results for saccades. However, when subjects had to keep gaze fixated at the target during the head movement, the overestimation of space was significantly stronger. Our data suggest that the compensation of the head movement by reflexive saccades is a necessary process in maintaining visual stability across gaze shifts.

Hemianopia, cycling and scanning behaviour in virtual and real environments

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Introduction

Mobility activities can be challenging for people with hemianopia since their visual field defect prevents them from obtaining a complete overview of their surroundings. Compensatory scanning behaviour helps them to overcome these problems. However, whether people with hemianopia also exhibit such compensatory behaviour during cycling has not yet been determined. In this study, we examined (i) whether people with hemianopia show compensatory scanning behaviour while cycling, (ii) whether this compensatory behaviour differs from scanning behaviour at the onset of hemianopia, and (iii) whether the reduced field of view (r-FoV) of a head mounted display (HMD) influences scanning behaviour while cycling.

Method

In our first experiment, we compared scanning behaviour between people with (i) hemianopia (N=8), (ii) simulated hemianopia (N=8), and (iii) unimpaired vision (N=8) while they cycled in a virtual environment displayed through a HMD. In a second experiment, participants with unimpaired vision (N=16) cycled in a real urban environment with and without a r-FoV (90°), while a mobile eye-tracker recorded their eye-movements. To assess the scanning behaviour of a participant, we computed the variance of their horizontal eye-positions, referred to as the dispersion.

Results

Dispersion did not differ between people with hemianopia, simulated hemianopia and unimpaired vision ($p>0.1$). Yet, we found more variation in dispersion between individuals in the hemianopia group compared to the other two groups. Moreover, we found that a r-FoV decreased the dispersion ($p<0.001$).

Conclusion

During cycling, individuals with hemianopia differ substantially in their dispersion, suggesting some exhibit compensatory scanning, while others do not. However, this outcome may have been affected by the r-FoV of the HMD, which reduces scanning in people with unimpaired vision. Further, we found no evidence that suggests that compensatory scanning behaviour may change over time. It remains to be determined whether compensatory scanning is linked to a better cycling performance.

Effect of saliency on gaze behaviour in VR Visual Search

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In typical visual search paradigms, all stimuli are within the field of view. However, in natural environments, head movements are required to search an area. In a VR experiment with 33 participants we investigated eye and head movements during search of salient or non-salient targets. To the right and left of a fixation point were two panels each, 35° (inner) and 70° (outer) from fixation. Each panel showed 2 letters in fixed positions. The inner panels were visible peripherally from the start, the outer panels could only be viewed by moving the head. Participants reliably fixated first on an inner panel (92%). If the target was not in the inner panel, they typically moved to the outer panel on the same side (61%). The participants' initial eye movement therefore had the same amplitude (21.8°) on most trials. Considering all trials with targets in the inner panels, participants started their search in the correct direction more often in salient than non-salient trials (73 vs 63%). We compared the effect of saliency on trials in which the target was directly found in the inner panel. While the onset and offset of the saccade occurred at similar times in salient and non-salient trials, the first fixation on the target occurred earlier in salient trials. The landing point of the first saccade was also closer to the target in salient trials than in non-salient trials. In trials without a target in the inner panel, when subjects proceeded to the outer panel and found the target there, the landing point was not influenced by salience. However, fixation of the target occurred earlier in salient trials. We find saliency increases the likelihood of detecting targets in the periphery before the first head and eye movements in a search. This mechanism was not found once a head movement was initiated.

Using AI-generated synthetic images to drive object responses in the human brain

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The human brain effortlessly categorizes objects at different levels of abstraction. An important question for our understanding of visual processing is to what extent this categorisation capacity is underpinned or driven by mid-level visual features (e.g., shapes and texture) that co-vary across different categories (e.g., animals or vehicles). Here we addressed this by training two independent Generative Adversarial Networks to produce two categories of novel synthetic stimuli that match the low- and mid-level visual features of either animate or inanimate real objects. Crucially, where these synthetic stimuli have the low- and mid-level visual properties of real objects, they have no associated high-level category labels. We recorded electro-encephalography and behavioural categorisation responses to the synthetic stimuli along with their real counterparts in a naïve participant sample. Results revealed animacy-like neural signatures for the synthetic objects that emerged earlier than neural signatures distinguishing the same stimuli from images of real objects. The temporal dynamics of neural responses suggest that successful animacy categorisation of our novel synthetic images was driven by their mid-level visual features. These findings contribute to a precise picture of how image statistics support successful object recognition.

Human shape perception spontaneously discovers the biological origin of never-before-seen stimuli

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We easily tell apart a shoe from a fish. This facility involves identifying shape features that objects have in common with other members of their class, and relies—at least in part—on semantic/cognitive constructs. For example, plants sprout branches, fish grow fins, shoes fit on our feet. What happens however when we are presented with novel objects of unknown origin? Can humans parse shapes according to the processes that give shapes their key characteristics, even when these processes are hidden? To answer this, we entered an environment alien to most humans: the microscopic realm of cells. Specifically, we investigated how humans perceive the shape of cells from the olfactory system of tadpoles of the African clawed frog Xenopus laevis. These objects are novel to participants, yet occur in nature and cluster into classes following their underlying biological function. We reconstructed 3D models of cells through 3D-microscopy and photogrammetry, and used these as stimuli in psychophysical experiments with human participants (N=36). In a multi-arrangement task, participants arranged 3D-printed cell models according to their shape similarity, and arrangements were recorded via passive-marker position tracking. Participants were highly consistent in how they arranged the novel stimuli ($r=.66; p<.001$) and spontaneously grouped the objects to reflect the cell classes, unwittingly revealing the underlying biological origin of the stimuli. In a video-based task, participants then rated 3D renderings of cells on a set of predetermined visual shape features. Principal component analysis revealed that ratings spanned a multidimensional perceptual space that linearly separated objects into their underlying cell classes and predicted stimulus arrangements from the multi-arrangement task ($r=.62; p<.001$). Further, support vector machine classifiers could recover cell class from perceptual ratings with 72% cross-validated accuracy (well above 25% chance). Our findings thus demonstrate that human perceptual organization mechanisms spontaneously parse the underlying biological origins of never-before-seen, natural 3D shapes.

Funding

DFG: 222641018-SFB/TRR 135 (C1); IRTG-1901 "The Brain in Action".

Hessisches Ministerium für Wissenschaft und Kunst: "The Adaptive Mind".

The representation of diverse visual material properties in the human brain

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Material properties carry critical information about objects, enabling a wide range of judgments and comparisons, as well as facilitating movement planning. Although material perception is crucial in our daily lives, we still know surprisingly little about how material properties are represented in cortex. Here we performed an event-related functional magnetic resonance imaging (fMRI) study to reveal the brain areas involved in the visual processing of a wide range of material characteristics. Across multiple scan sessions, participants were each presented several times with 600 material images spanning 200 material categories from the STUFF dataset (Schmidt, Hebart, Schmid & Fleming, 2023). Representational similarity analysis (RSA) was used to compare activity patterns in 14 functionally-defined regions of interest (ROIs) with perceived similarities derived from over 1.5 million triplet similarity judgments of the images from the dataset (Schmidt et al, 2023). Our data suggest that from lower (i.e., V1-V4) to higher order visual areas (e.g., FFA, PPA), the correlation in neural response to different pairs of material images increased (mean correlation $r = 0.27$ for lower areas and 0.45 for higher areas). Schmidt et al also derived 36 perceptual dimensions from the similarity judgments (e.g., metallic, fibrous). We used a General Linear Model (GLM) to identify regions that correlated with each of these dimensions. Specifically, we compared neural responses to the 10 top-scoring vs. 10 bottom-scoring images from the similarity judgments for each material dimension. This yielded distinct activity associated with each dimension, spanning a wide-range of visual and cross-modal brain areas. This research presents the most comprehensive cortical mapping of material categories and properties to date.

Reference: Schmidt, Hebart, Schmid & Fleming (2023). Core dimensions of human material perception. PsyArXiv, 10.31234/osf.io/jz8ks.

Acknowledgments: Funded by the DFG (222641018 – SFB/TRR 135 TP C1) and the HMWK ("The Adaptive Mind").

Interactive images for visual material communication

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Consumers cannot touch online products, which impairs the fidelity of their impressions. To accommodate this haptic deprivation, we designed visual interactions that mimic the interactions consumers normally would have when touching. To quantify the expectations raised by these interactive images, we first quantified the perceived properties of the fabric stimuli. We analysed pairwise comparison data from the four attributes 'softness', 'thinness', 'shininess' and 'elasticity' with Thurstonian scaling. This first lab experiment revealed that softness was an attribute that is twice as discriminable than the other attributes, as quantified by the Thurstonian-based metric NDL (Number of Distinguishable Levels). In following experiments we compare the lab scaling data with the data from online experiments where we showed three visual interactions: 1) dragging the fabric over a cylindrical object, 2) moving the fabric vertically and draping on ground, and 3) stretching the fabric. We analysed the data by computing Kendalls' Tau correlations between the lab and online experiments for all four attributes. We found that each visual interaction addresses different attributes although not entirely as predicted. For example, the stretch interaction was significantly for 'thinness' but not for the other attributes. Overall, softness and thinness seem to be best visually communicated while shininess and elasticity the least. The results show that we can reproduce tactile impressions online and that the methodology to quantify differences between expectation and reality works. This will serve as a useful basis for future studies investigating other product categories and other visual design possibilities.

Behavioral detectability of optogenetic stimulation of inferior temporal cortex varies with the visibility and size of concurrently viewed objects.

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We have previously demonstrated that macaque monkeys' ability to behaviorally detect a subtle optogenetic impulse delivered to their inferior temporal (IT) cortex depends on some characteristics of the images viewed at the time of stimulation. This observation raises an intriguing question about the phenomenological nature of the perceptual event induced by stimulation: Does stimulation of the same neural population induce a consistent perceptual event, independent of the concurrently fixated image, that is more or less difficult to detect due to figure-ground effects? Or does stimulation induce a variable perceptual event depending on the concurrent visual input? To tease apart these two interpretations, we tested how diminishing the visibility of the visual input affected detection of the cortical event. In one experiment visibility was diminished by reducing the contrast, saturation, and spatial frequency of the objects viewed during stimulation. In a second experiment visibility was diminished by reducing object size. If cortical stimulation evokes a consistent perceptual event, it should be similarly if not more easily detected when the onscreen images are less visible. Two monkeys were implanted with LED-arrays over a region of their central IT cortex transduced with the depolarizing opsin C1V1. In each trial an image was displayed on the screen for 1s. In half of trials, randomly selected, an LED was turned on for 200ms halfway through image presentation. The animal was rewarded for correctly identifying whether the trial did or did not contain cortical stimulation. Attenuating objects' visibility by diminishing their contrast, spatial frequency, and saturation significantly decreased detection performance (ANOVA: M1 $p = 0.004$, M2 $p < 0.001$), as did reducing their size (M1 $p = 0.01$, M2 $p < 0.001$). These results show that identical stimulation impulses induce variable perceptual events depending on the visibility of the objects viewed at the time of stimulation.

Neural mechanisms of costly helping in the general population and mirror-pain synesthetes

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Helping someone in need often comes with a cost to ourselves. It has been proposed that feeling the pain of others as if it were our own is a key motivator when engaging to help. Here we investigate how individuals that report somatically feeling the pain of others in their lives (mirror-pain synesthetes) differ from those that do not, when given the decision to help and reduce someone's the pain conveyed through different modalities. Mirror-pain synesthetes and participants who do not report such everyday life experiences witnessed a confederate expressing pain and could decide to reduce the intensity pain by donating money. Measuring brain activity using functional

magnetic imaging (fMRI) confirmed our initial hypothesis: self-reported mirror-pain synesthetes increased their donation more steeply, as the intensity of the observed pain increased, and their somatosensory brain activity (in SII and the adjacent IPL) activity was more tightly associated with donation than for participants not reporting mirror-pain synesthesia, when the pain of others was conveyed by the reactions of the pain-receiving hand (Hand condition). For all participants, in a condition where the pain was conveyed by facial expressions (Face condition), activation in insula, SII and MCC correlated with the trial by trial donation made, while SI and MTG activation was correlated with the donation in the Hand condition. The use of neurological signatures for observation of pain, experience of pain and experience of guilt revealed that these neural processes are associated with the level of helping. These results further inform us about the role of empathy in costly helping, the underlying neural mechanism, and inter individual differences.

The Influence of Hatha Yoga on Stress, Anxiety, and Suppression

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Mindfulness-based interventions may alleviate human stress and anxiety. They also influence the ability to suppress distraction. In our study, we were interested in how the two effects are related. Does mindfulness training help suppress distraction and thereby decrease stress and pain? To answer this question, we used Hatha Yoga, a mindfulness intervention. We tested if the intervention improved participants' ability to selectively suppress distractions, and decreases self-reported stress, stress reactivity, and anxiety, besides increasing mindfulness. Our study included 98 healthy yoga novices between 18 and 40 years that were randomly assigned to either an experimental or a waitlist condition, with each participant completing pre- and post-intervention assessments including questionnaires, electrophysiological and behavioral measures. After eight weeks of yoga practice, significant reductions in self-reported stress and stress reactivity levels, as well as increased mindfulness were observed among those receiving the intervention relative to those in the waitlist control group; however, there were no significant changes in state, nor trait anxiety due to the intervention. Also, the stress changes did not significantly correlate with increased suppression in the experimental task: Suppression was not affected by our intervention and was not responsible for found stress reductions. Overall, our findings suggest that regular participation in Hatha Yoga can improve mental health outcomes, without impacting cognitive functioning directly related to distractor suppression.

Neural dynamics supporting context-based social perception in health and disease

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Perceiving others' actions activates a set of frontoparietal regions collectively termed the Action Observation Network (AON). Classically, this topic has been studied using isolated movements devoid of context which precludes the possibility of examining the neural mechanisms underlying action comprehension in more ecological settings. Furthermore, a neural description of the spectro-temporal underpinnings supporting this process, as well as their potential reorganization in the presence of brain damage are currently missing. To address these gaps, we investigated (1) the role of brain oscillations in the context-based perception of others' actions, and (2) whether brain tumors infiltrating AON hubs (such as the IFG) lead to compensatory plasticity within this network.

We recorded behavioral responses and magnetoencephalographic (MEG) signals of healthy participants and patients with left frontal tumors as they performed an action observation task. In this task, participants watched snapshots depicting ongoing non-fully executed actions in congruent or incongruent contexts, and had to predict action unfolding.

Behaviorally, participants were better at recognizing actions embedded in congruent as compared to incongruent contexts. At the oscillatory level, the AON exhibited stronger mu (8-13 Hz) power decreases during action observation compared to static hand observation. Congruency effects in healthy participants involved early fronto-temporal power increases in the theta band (4-8 Hz, starting ~150ms), followed by sensorimotor mu modulations (~200-450ms) within the left hemisphere. In contrast, patients showed similar effects but in the right hemisphere. Our findings suggest that (1) the retrieval of semantic knowledge about objects present in the scene modulates AON activity at early stages, likely biasing motor representation selection (2) and that this mechanism shows a compensatory rightward shift in the presence of left frontal damage. Overall, our results provide insights into the neural signatures of context-based social perception in health and disease, highlighting the importance of semantic knowledge in shaping motor resonance.

Social Perceptual Grouping is Sensitive to Group Size

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The human visual system is well-tuned to detect human agents and the relationships between them. For example, past work has shown that groups of two are found faster when the two individuals are facing towards (versus away from) each other. Everyday life however often involves groups larger than two, and so here we examined if a perceptual search advantage also existed for facing groups of three or more. Participants searched for groups of facing individuals in arrays of non-facing individuals or groups of non-facing individuals in arrays of facing individuals. Experiments 1 - 3 showed that facing triads (or groups of three) were found faster than non-facing triads. This search advantage was not driven by perceptual grouping of dyads within the triads and was in part influenced by the perception of body orientation. Experiments 4 and 5 manipulated group size from two to eight and indicated that the magnitude of the social search advantage was greatest for smaller facing groups of less than 4 or 5 individuals. Human perception may thus mirror social interactive preferences in real life, as humans most often spontaneously congregate in interactive groups smaller than five. Collectively, these results demonstrate that human perception appears to be well-tuned to represent not only simple dyadic relationships but also more complex group social structures.

Integrative processing in artificial and biological vision predicts the perceived beauty of natural images

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Previous research strongly suggests that whether we assign beauty to natural images is already decided during perceptual analysis. However, it is still largely unclear which perceptual computations give rise to the perception of beauty. Theories of processing fluency suggest that the ease of processing for a specific stimulus determines its perceived beauty. Here, we tested whether perceived beauty is related to the amount of spatial integration across an image, a perceptual computation that reduces processing demands by aggregating image elements into more efficient representations of whole images. We reasoned that increasing amounts of integration reduce processing demands in the visual system and thereby lead to an increase in perceived beauty. We quantified integrative processing in an artificial deep neural network model of vision: We compared activations between parts of the image and the whole image, where the degree of integration was quantified as the amount of deviation between activations for the whole image and its constituent parts. This quantification of integration predicted the beauty ratings assigned to images across four studies, which featured different images and task demands. Complementary fMRI recordings revealed that the integration in human visual cortex predicts perceived beauty in a similar way as integration in artificial neural networks. Together, our results establish integration as a computational principle that eases perceptual analysis and thereby predisposes the perception of beauty.

Glare's calculated patterns of light on retinal receptors

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Vision has two independent spatial transformations: optical and neural. First, optical glare transforms scene luminances into different light patterns on receptors (retinal luminances). Second, neural spatial-processing generates appearances that are inconsistent with receptor's responses (Contrast; Assimilation; Land's Black&White Mondrian; Adelson's Checkershadow). Computed optical glare describes the input to neural-spatial vision. Our new Python program calculates light patterns on receptors by convolution with Vos & van den Berg's CIE Glare Spread Function. We studied Lightness Illusions containing pairs of uniform, equiluminant Gray regions-of-interest. Glare transforms equal Grays into unequal non-uniform retinal gradients. Discontinuous edges become rounded high-slope continuous contours.

Contrast Illusions have large Gray rectangles in larger White&Black surrounds. Michael White's Assimilation has narrow Gray stripes in equal-width White&Black stripes. White scene segments are glare's largest sources. After glare, Grays show moderate, and Blacks show major distortions. Pixels' glare sums depend on the size of scene elements, and angular separation from glare sources. CIE Glare standard decreases 8 log10 units over 60°. The convolution sums the diminishing amounts of light (with increasing separation) from all pixels onto all-other pixels.

Observers report Contrast's Grays-in-White appear darker, despite glare-generated higher retinal luminances. Also Grays-in-Black appear lighter, despite less glare light. Observers report Assimilation's Grays-in-White appear lighter, with more glare light: Grays-in-Black appear darker, with less glare light. For glare, segments' angular sizes, and their separation from White segments matters.

Glare calculations of Land's Black&White Mondrian, and Adelson's Checkershadow show the same after-glare effects. Despite Illusions low dynamic range (200-1), Lightness Illusions are ideal targets for studying glare's distortion of light patterns on the retina. Surprisingly, Blacks segments appear uniform despite considerable range of retinal non-uniformities. How does Spatial Vision make receptors' variable responses within Gray and Black segments appear perceptual uniform?

Modelling age-related changes in spatio-chromatic contrast sensitivity across a large luminance range

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Decline in visual performance is one of the challenges associated with normal ageing. Contrast sensitivity functions (CSFs) are a reliable indicator of the performance of the human visual system and age-related changes in CSFs can quantify the different kinds of visual performance losses that occur with ageing. We measured contrast sensitivity data for a younger group (n=24; mean age=27) and an older group (n=20; mean age=65) of observers. The stimuli were Gabor patches of 5 spatial frequencies (0.5 - 6 cycles per degree (cpd), each spanning 2 cycles) modulated across three colour directions (achromatic, red-green, yellow-violet), which were displayed at luminances ranging from 0.02 to 2000 cd/m^2 on a custom projector-based high-dynamic-range (HDR) display.

We found a systematic decline in contrast sensitivity in older observers as compared to younger observers. We modelled the CSFs (w.r.t. spatial frequency) of each observer for each combination of colour direction and luminance as a log-parabola function with three parameters: peak sensitivity (highest sensitivity across all spatial frequencies), peak frequency (spatial frequency at the highest sensitivity) and the bandwidth. Then, we modelled those parameters as functions of age.

Our proposed empirical model showed that the peak sensitivity in achromatic stimuli was not affected by age whereas the peak sensitivity in chromatic stimuli only declined at low luminances for older observers. Peak spatial frequency decreased by 0.04 cpd/decade of age for achromatic, by approximately 0.2 cpd/decade for red-green stimuli, and remained unaffected for yellow-violet stimuli. The bandwidth of achromatic, red-green and yellow-violet stimuli decreased by 0.14, 0.2 and 0.06 dB/decade respectively.

Our empirical model represents both optical and neural age-related losses as it establishes that although contrast vision loss increases with higher spatial frequencies, the magnitude of this loss is dictated by the mean luminance and the chromatic modulation direction of the visual input.

Adaptative binocular disparity behaviours in response to contrast changes in a reading-like task

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We investigate how the visual system reacts and adapts to a continuous text-background contrast in a number-reading task. In this reading-like task, the background becomes more and more faded while the text stimuli across a single line stay bright and white, with decreasing contrast and increasing reading difficulty. We studied adaptative binocular behaviours in terms of fixation disparity—the typically small location difference between the fixation points of the two eyes, using eye-tracking. We found a systematic adaptation of binocular vision in response to the contrast change, with an overall crossed tendency of binocular fixations; i.e. left eye's fixation point to the right of the right eye's fixation point. As the contrast reduced and reading difficulty increased, numbers of crossed fixations increased and size of the fixation disparity decreased, across the single line of the stimulus.

These overall behaviours suggest a potential processing advantage for crossed fixations. As reading difficulty increases, more crossed fixations and smaller disparities indicate a 'zooming in' to a particularly difficult-to-read section of the line. It suggests the capacity to project the critical region between the two fixation points onto a larger area of cortex, so as to increase the resources being devoted to reading the numbers.

A crossed fixation means that the stimulus lies beyond the horopter, the point of intersection of the two lines of sight. The stimulus therefore appears to the higher visual processing to be further away, beyond the horopter. More processing resources are devoted to more distant stimuli. In this case, the additional resources aid in interpreting the contrast-degraded stimulus.

This binocular contrast adaptation through very peripheral muscle-driven movements of the eyes implies an effect in which the cortical processing that contributes to cognition is intimately synchronised with the neural circuits controlling eye-movements.

Contour erasure reveals local mechanisms underlying perceptual filling-in

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Contour erasure describes the phenomenon when an object disappears into the background after brief adaptation to an

outline of the object contour. The underlying mechanism of contour erasure and its relationship with perceptual filling-in remain elusive. Previous work revealed that contour adaptation increased the contrast threshold of a subsequently presented target. Two hypotheses are tested here. First, if contour erasure renders the target invisible by inhibiting whatever is presented in the target area, the target threshold should be independent of background luminance. The second hypothesis assumes that contour erasure facilitates filling-in of the target region with the surround, implying that contour erasure should be most effective when target and the background regions have the same luminance. Here, target and pedestal were crescent-shape objects with 2° in width and length either of positive or negative polarity. The contour adapter was flickering high-contrast outlines of the target regions. All stimuli were presented 5° left and right of fixation. In our spatial two-alternative forced-choice paradigm, on each trial two contour adapters appeared in the target regions, flickering at 3Hz for 1.5s, followed by two pedestals (duration: 83.3ms) with the target randomly superimposed on either the left or right pedestal. The adaptation background was always at mean luminance level (70 cd/m2), whereas the test background either remained at mean luminance or it increased or decreased with the pedestal luminance. We implemented a Bayesian adaptive staircase method to estimate the target threshold at 86% accuracy. The results indicated that the contour erasure effect was maximum ($p < 0.05$) when the test background and the pedestal had the same luminance for both target increments and decrements. These findings suggest that contour erasure paradigm can be used to reveal local mechanisms underlying perceptual filling-in.

Acknowledgement: This study is supported by the DFG (Deutsche Forschungsgemeinschaft) GR 988/27-1 and NSTC (National Science and Technology Council) 110-2923-H-002-004-MY3

Individual differences in crowding and their impact on feature and conjunction search

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Visual search is an integral part of human behavior, involving mechanisms of perception, attention, memory, and oculomotor control. Most of the information used during visual search comes from the periphery of our vision, with all its inherent sensory and attentional constraints. Functional viewing field (FVF) theories posit that those constraints are the major determinants of search efficiency. We adopted an individual differences approach to test the prediction that visual search performance is determined by the efficacy of peripheral vision, in particular crowding. We found that susceptibility to crowding (as measured by critical spacing) is predictive of slower search, more eye movements, and longer fixation durations in a single feature-search task. In a follow-up study, we characterized crowding for different feature dimensions (color, orientation, and their conjunction) and show that these same measures are also modestly predictive of conjunction search. At the same time, we observed a strong color selectivity in search, suggesting that conjunction search behavior relies more on top-down feature-specific guidance and is therefore relatively less determined by sensory limitations as caused by crowding.

Impact of crowding on visual appearance in Amblyopia

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Amblyopia is a developmental disorder of spatial vision characterized by reduced visual acuity (VA). VA is commonly evaluated by letter identification tasks in which observers are constrained to specific response categories and performance is scored as correct/incorrect. However, such tasks do not reveal any detailed information about stimulus appearance. Previous research has found that persons with amblyopia perceived isolated stimuli as more distorted and had stronger foveal crowding (i.e., worse performance with flanked targets) than normal observers. Here, we captured the appearance of crowded and isolated letters in amblyopes and controls. High contrast letters were presented in the fovea for 500ms, either crowded (with black bars on all sides) or isolated at the observer's VA threshold and at 1.5 times the threshold size. Observers viewed the target letter monocularly with their dominant/fellow or non-dominant/amblyopic eye and replicated target appearance on a 9x9 square-grid interface with binocular viewing. Each square in the interface could be turned on and off with mouse clicks and their grey levels adjusted with the mouse wheel. Responses revealed significant deviations from the target, including truncation and extension of elements, fusion of separate elements (e.g., connecting the flankers) and shape distortions (e.g., depicting straight lines as curves) for both groups in all conditions. Importantly, amblyopes' depictions were found to have less structural similarity to the target than controls', particularly when crowded (mean similarity score of 0.53 ± 0.02 vs. 0.67 ± 0.03 for amblyopes' depictions and controls', respectively). Interestingly, amblyopes' depictions were also of lower contrast than controls'. Taken together, our results reveal characteristics of target appearance in both groups showing stronger visual distortions in amblyopes than controls. These results highlight important differences between normal and amblyopic visual

perception, and show the stronger impact of crowding –and its correlates of appearance– in the amblyopic (vs. normal) fovea.

Temporal modulation of redundancy masking

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In redundancy masking, the number of perceived items in repeating patterns is reduced. For example, when observers are presented with 3 identical, radially arranged lines in the periphery, they often report seeing only 2 lines. Several spatial factors modulate redundancy masking, such as the spacing between items, the regularity of their arrangements, and item size. However, if and how temporal factors modulate redundancy masking has not yet been investigated. Here, we studied the effects of presentation time in redundancy masking using a backward masking paradigm. Stimuli consisted of 3, 4, and 5 radially or tangentially arranged line arrays displayed randomly to the left or right of fixation (at 10.14° eccentricity). Spacings between the lines were varied to prevent the use of overall array extents as a cue to the number of lines presented. Presentation times were 24, 47, or 71 ms in different blocks. A noise mask followed the lines at various interstimulus intervals (0, 35, 71, 106, or 141 ms). In an additional condition, no mask was presented (baseline). Observers indicated the number of lines they perceived. As expected, the number of lines reported was lower in the radial than in the tangential arrangements in (almost) all conditions. In radial arrangements, there was strong redundancy masking with 4 and 5 lines, but surprisingly, not with 3 lines. In the masking conditions, there was no effect of presentation time; however, there was a small trend for reporting the correct number of lines with increasing interstimulus intervals. Interestingly, in the baseline conditions, redundancy masking became stronger with increasing presentation times. Overall, there were strong individual differences. Taken together, our results suggest that temporal factors modulate redundancy masking and may have opposing effects for different numbers of objects, possibly related to differences between subitizing and numerosity estimation.

Is visual angle equal to retinal angle?

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In visual psychophysics and perception research, visual angle is commonly assumed to be the same as retinal angle, based on familiar drawings of chief rays as straight direction lines that pass through a single point in the eye. This concept dates back to Volkmann's treatise in 1836 and it has persisted because for small angles it is correct for nodal rays that pass through the 2nd nodal point, and for large angles it is also correct if, following Volkmann's cautionary remark, the lines are thought of as directions rather than rays. In practice, actual rays are refracted at the cornea and the lens, and even for paraxial rays it is only the input and output angles that are identical. The simplified drawing allows visual angle to be related to distance along the retinal surface, which can be used to translate anatomical size estimates of the fovea or macula to visual angles. Yet with rays passing through the pupil it is misleading as to the range over which the equality of angles holds; there is extremely high linearity to over 60 deg of visual angle, and a very modest increasing nonlinearity thereafter to beyond 100 deg (and the intuition from the graph might reinforce a common misconception the visual field were limited to 90 deg sideways). The situation is different for patients who have had cataract surgery because far peripheral rays might bypass the intraocular lens, causing the perception of bothersome dark shadows. Here we present an intuitive graph, using ray-trace software, to cover the whole horizontal meridian up to its limits, and results are compared to those from the ophthalmic literature. In sum, visual angles in the visual field map to distance in mm along the retinal surface by a close-to-linear function, with modest non-linearity at very large angles.

AIM+ (Angular Indication Measurement) Efficient Assessment of Multidimensional Functions

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Visual function assessment is an essential component of basic research and clinical practice, and comprehensive screening requires the administration of multiple specialized tests to monitor health across specialized visual pathways. Such a battery requires significant resources to administer, particularly when performance depends on multiple parameters. We have previously introduced AIM (Angular Indication Measurement), in which psychophysical paradigms are expressed as orientation judgments and psychometric functions are fit to orientation report errors, and we have shown AIM's efficacy for the assessment of visual outcomes including acuity, contrast sensitivity, stereoacuity, color, form and motion across multiple high- and low-functioning populations. Here, we generalize the approach to 2D functions for suprathreshold performance measurements of threshold versus contrast (TvC) and equivalent noise (EN). These paradigms interrogate sources of functional impairment and provide critical insights into healthy and pathological processes during development and aging, but are not widely used because of task complexity and test duration. In AIM+TvC, participants indicate the orientation of gratings presented on

pedestals of matched spatial frequency band-pass filtered isotropic noise of a range of contrasts. In AIM+EN, observers report the mean orientation of dipoles (EN form), the direction of drifting dots (EN motion) or dot colors (EN color) whose individual orientations/directions/colors are drawn from distributions of varying standard deviations. In a variety of healthy and impaired populations, we show that TvC and EN parameters measured with AIM+ are not significantly different from those estimated with standard 2-AFC methods, but are measured in less than 5 minutes, compared with more than 20 minutes for 2AFC tasks. Furthermore, AIM+ tasks are easy for low-functioning participants to learn and transfer across tasks. AIM+ therefore has the potential to improve the assessment of the integrity of visual processing pathways and to assist in the diagnosis and monitoring of visual development and degeneration, without compromising the quality of data collected.

Shape from shading consists of pre-attentive and attentive processes

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The term "shape-from-shading" refers to the process of recovering the three-dimensional shape of an object from its two-dimensional shaded image. This is possible because shading, combined with the direction of illumination, informs us about local surface shape by exploiting the fact that the parts of the surface facing the light source are brighter than those facing away. Shape from shading has long been thought to be a pre-attentive process, which happens automatically and in parallel to other processes and across the visual field. This notion is mainly based on findings from pop-out experiments, the observation that the assumed light source direction is computed in a retinal, rather than an environmental reference frame, and the involvement of early visual cortex in shape from shading. However, recent finding, using pupillometry data, suggested that shape from shading does require attention. We suggest that shape from shading consists of two distinct processes. Some information on shape from shading may be processed fast, in a pre-attentive manner, to allow a fast segregation from background. However, in order to progress to shape identification, where the exact shape is perceived, top-down attention must be involved. Implications of this suggestion will be discussed.

Intra-object brightness contrast influences perceived time to collision

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Previous studies have shown that time-to-collision (TTC) judgments for solid gray objects remain stable across variations of object brightness and brightness contrast to the background. However, under natural viewing conditions brightness contrasts additionally occur between different areas of the objects surface. In the present study, we investigated whether observers rely on such internal contrasts when judging the TTC of an approaching object. We presented a diamond-shaped object, composed of four squares, against a uniform gray background on a computer monitor. The squares were either solid gray or had four different shades of gray, with small or large range brightness variation, resulting in lower or higher inner contrast. The average brightness of the object remained constant across all conditions. The background was brighter or darker than the object in 50% of the trials, while maintaining average object-to-background contrast. In a further configuration, we used the same brightness specifications but separated the four squares by adding random interspaces between their neighboring edges. In a prediction motion task, each of the 30 participants performed two TTC judgments for all combinations of object size (72, 108, 144 cm), presentation time (1, 2, 3 sec), extrapolation time (1, 1.5, 2 sec), inner contrast (none, low, high), background brightness (low, high), and object configuration (closed, separated), resulting in 648 trials. The approaching speed was set constant at 4 m/s. When the object configuration was closed, we found later TTC judgments for conditions with inner contrast compared to solid gray. This indicates that the internal contrast of an object is factored into TTC judgments. In addition, we found earlier TTC judgments for the separated compared to the closed object configuration, which can be attributed to the increased visual angle spanned between the four individual squares.

Visual function in non-overlapping visual field defects: dichoptic experiments in healthy subjects with simulated scotomas

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Purpose: In clinical care, glaucoma patients are commonly considered to have normal vision as long as each point in visual space is perceived by at least one eye. However, eyes may be affected unequally and visual field defects may occur in different locations between the eyes (non-overlapping visual field defects [NOLVFDs]). Aim of this study was to find out if NOLVFDs can hamper certain visual functions by simulating these defects for healthy participants.

Methods: For this preliminary analysis, we included 9 healthy human volunteers in a cross-sectional observational study. After screening participants for normal intraocular pressure, mean peripapillary retinal nerve fiber layer thickness, retinal ganglion

thickness, visual field, and stereoscopy, they participated in four different psychophysical tests. These tests targeted (1) minimum perceived amplitude of movement, (2) coherent motion perception, (3) contrast sensitivity, and (4) shape recognition. Tests were performed in different viewing conditions, namely binocularly, monocularly, and binocularly with simulated NOLVFDs. Participants' scores in each test were compared among different viewing conditions using repeated measures ANOVA.

Results: The minimum perceived amplitude of movement was significantly lower in the binocular condition compared to monocular and NOLVFDs, but there was not a significant difference between monocular and NOLVFDs. In coherent motion perception, participants performed significantly worse in NOLVFDs compared to the binocular condition, but the post-hoc tests failed to show a significant difference between monocular and NOLVFDs or Monocular. In the contrast sensitivity test, the performance in different viewing conditions was significantly different, but post-hoc tests failed to show the pattern of this difference. Finally, in the shape recognition test, participants' performance was significantly worse in NOLVFDs condition compared to binocular and monocular conditions and performance in binocular condition was significantly better than monocular condition.

Conclusions: Non-overlapping visual defects may hamper minimum perceived amplitude of movement, coherent motion perception and shape recognition which are visual functions that are not routinely evaluated in clinical practice.

THEORETICAL CONSEQUENCES OF THE MANIATIS VARIATION OF SLC

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Anchoring theory (Gilchrist et al., 1999) proposes that in Simultaneous Lightness Contrast (SLC) effect, target is computed relative to its local framework (white and black backgrounds). Target on the black background is perceived lighter than its actual value, because it is the highest luminance in its local framework. Maniatis (2015) challenged this account by modifying the SLC display. She added a white surface on the black background preventing that target from being an anchor in its local framework. According to the Anchoring theory, this should eliminate SLC effect, but this did not happen.

In order to resolve the Maniatis dilemma we tested (in an online experiment) the original SLC, Maniatis variation, and 9 similar stimuli in which we varied size, number, and the position of the added white surfaces. 34 participants matched the lightness of the targets by adjusting the lightness of the patch presented on the screen.

Original SLC produced the expected effect: target on the black was perceived as being lighter than the target on the white background (Md = 12,470, p = .002). Maniatis variation also produced typical SLC effect (Md = 11,176, p = .001). However, it is possible to eliminate the SLC effect either by adding more white surfaces (Md = 6,742, p = .026) or placing the targets on a black and white backgrounds in a particular configuration (Md = 8,016, p = .089). Additionally, good grouping of the white surface with the target weakens the illusion.

Maniatis offered an important challenge for the Anchoring theory. However, it did not simply demonstrate the role of the anchor in the local framework, but as our results showed, the importance of spatial configuration and grouping principles. The theory at the moment does not include these factors. Further theoretical implications will be discussed.

Exploring the contrast sensitivity function through noise equivalent contrast

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The visual system can be affected by internal noise, which can interfere with weak signals and reduce sensitivity to a target. Noise Equivalent Contrast (NEC) is a measure of the minimum detectable contrast in the presence of additive external visual noise. It is a way of characterising the visual system's ability to detect low-contrast signals in the presence of a controlled amount of noise. By estimating the NEC, we can determine how much noise the visual system can tolerate before the signal becomes undetectable. Although previous research has shown that the NEC method is effective in determining sensitivity to stimuli (Pelli & Farell, 1999), direct application of this method to the detection of objects in natural imagery is limited by disproportionate interactions between the additive noise and target spatial frequencies.

To address this issue, our study aims to develop a methodology that can be applied to targets that are simultaneously fixed in contrast and varied in size. We investigate whether adding an external 1/f noise mask to a fixed-contrast target Gabor stimulus in a 2afc orientation discrimination task at a range of spatial frequencies leads to a replication of the usual spatial contrast sensitivity function as measured without additive noise. Based on our findings, it appears that the spatial frequency of a target determines the sensitivity to the noise mask in a visual detection task. We also observed a pattern similar to that of a

contrast sensitivity function. The study aims to replicate the NEC method in conjunction with a visual detection paradigm to validate its effectiveness for the use in visual search tasks with natural imagery.

Effects of Delay Adaptation on Multisensory and Motor Integration for Duration Reproduction

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Subjective time can vary from physical time depending on the multisensory inputs we use. The brain integrates all available information to create a coherent perception. When temporal discrepancies arise across different modalities, the brain attempts to adapt to new cross-modal or sensorimotor relationships. The mechanism by which we adjust to different multisensory and motor timing for delay adaptation is still debated. To investigate this, we conducted two experiments on duration reproduction. In Experiment 1, participants were asked to reproduce a visual duration, while in Experiment 2, they had to reproduce a tactile duration. During the adaptation phase, an onset delay of 150 ms was introduced between participants pressing a button (motor) and the action effect (visual or tactile stimulation). We also included a baseline reproduction without the action-effect delay for comparison. After each adaptation phase, a testing phase was conducted with various action-effect delays (ranging from 0 to 150 ms). The results showed that the reproduced duration in the test phase was influenced by both delay adaptation and the action-effect delay. Participants partially incorporated the 150 ms delay from the adaptation phase in the reproduced duration, with 72 ms (visual delay, Experiment 1) and 107 ms (tactile delay, Experiment 2). Additionally, the testing reproduction increased as the action-effect delay increased, but the contribution of the action-effect delay was higher for the tactile modality (91%) than the visual modality (52%). This suggests that participants relied more on tactile feedback than visual feedback in duration reproduction when the action effect was delayed. Overall, our findings suggest that delay adaptation is influenced by the integration of multisensory timing and motor timing. The integration is weighted differently across modalities, with a higher sensitivity on the tactile modality than the visual modality.

No pooling in crowding: Deterioration of orientation discrimination with increasing numbers of identical Gabors

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Crowding is the deleterious effect of flanking objects on target perception. Pooling models suggest that signals from the target and the flankers are averaged. A prototypical example in which averaging is well defined is the averaging of orientation signals of Gabor targets and flankers of varying orientations. Here, we show that averaging accounts failed when the Gabors had identical orientations. Stimuli consisted of 1, 2, 3, 5, or 7 Gabors, randomly presented to the left or right of fixation, with the innermost Gabor presented at 10° eccentricity. Gabors formed two types of contours: 'snakes' where Gabors were oriented aligned with their path, and 'ladders' where they were oriented perpendicular to their path. In two conditions, the Gabors were presented in radial or tangential arrangements, typically expected to yield strong and weak crowding, respectively. Participants indicated the orientation (left or right) of the Gabor(s). All Gabors had identical orientations on a given trial. Participants in Experiment 1 were not informed about the identical orientations; in Experiment 2 they were informed (prior to the experiment). The pattern of results was the same in both experiments: Performance was similar, with comparably small variance between the different numbers of Gabors, in the tangential ladder and snake and the radial ladder conditions. However, discrimination performance strongly deteriorated with increasing numbers of Gabors in the radial snake condition. Interestingly, in both experiments, observers reported that the arrays often appeared to consist of Gabors with varying orientations. Our results show that orientation signals in the radially arranged snakes were not averaged, but instead subject to deleterious spatial interactions that cannot be accounted for by pooling. Using stimuli ideally suited to show pooling, our findings add to the increasing number of 'special cases' in which pooling models fail, challenging their ability to account for spatial interactions in vision.

Confidence in the Rapid Assessment of Peripheral Crowding Strength

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Crowding, the inability to distinguish an object in the presence of clutter, is not regularly assessed due to time-consuming and demanding procedures. We previously demonstrated that peripheral visual crowding can be assessed most rapidly using a continuous serial search (SS) paradigm with saccadic eye-movement responses (EMR). This conclusion was based when considering a fixed number of trials. However, this may favor certain paradigms over others. Here, we revisit the question of how crowding can be assessed rapidly, taking confidence in the threshold measurement into account.

In the experiment, we compared SS to conventional 2AFC and 6AFC paradigms using either manual responses (MR) or EMR. 15 participants completed the tasks in random order. The orientation discrimination threshold was measured using QUEST in crowded and isolated conditions. We reanalyze our data while considering a stop criterion based on obtaining a fixed confidence in the threshold.

To re-evaluate the duration of the paradigms, we calculated the number of trials required to obtain a threshold with a CI range < 20.5. Results revealed that the SS paradigm (217s) was faster than 2AFC (427s) and 6AFC with MR (337s) and as fast as 2AFC (284s) and 6AFC with EMR (234s).

Previously we also observed more crowding in the SS and 6AFC paradigms with EMR than in the 2AFC paradigms. To understand this, we now investigated whether the position of the stimulus elements in the 6AFC paradigm may have affected crowding strength. However, the results revealed no difference in the percentage of incorrect responses between the different locations in AFC paradigms.

We conclude that prioritizing confidence in the estimate of crowding strength affects the rapidity of a paradigm. Furthermore, since crowding does not differ between visual field locations, both the SS and 6AFC EMR paradigms can serve as rapid and reliable tools for assessing crowding.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie-Sklodowska-Curie grant agreement No:955590

Crowding reduces reading speed and comfort

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As you read this abstract, how would your reading speed and comfort change if it were written in a tight, squiggly, display font? We measured visual crowding, reading speed, and comfort for various fonts. Each of 41 online participants completed a crowding and a reading-comfort task via www.EasyEyes.app for six different fonts. The 12 tested fonts ranged from common text fonts (e.g., Times New Roman) to unique display fonts (e.g., Extenda, which is very tall, narrow, and tight). In the crowding task, participants were asked to identify the middle of three letters presented at –5o or +5o eccentricity along the horizontal meridian. QUEST varied center-to-center letter spacing to estimate the 70% identification threshold. The three letters were typeset as one string, and we varied point size to control average center-to-center spacing. We achieved good fixation by asking participants to click the center of a moving crosshair at the beginning of each trial and presenting the target for only 150 ms to avoid saccades to the target. We used the participant's webcam to maintain a 50 cm viewing distance. In the reading task, participants read excerpts from the children's book The Phantom Tollbooth followed by a reading-retention task. Then they rated (1 to 7) how comfortable they felt reading that font. We also measured reading speed. We found negative correlations between crowding and comfort ($r = -0.6$, $p < 0.001$) and crowding and reading speed ($r = -0.4$, $p < 0.001$). Reading speed and comfort are positively correlated ($r = 0.3$, $p < 0.001$). Overall, our results indicate that crowding makes reading slower and less comfortable.

Redundancy masking in regular and irregular patterns

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In redundancy masking, the number of perceived items in repeating patterns is reduced. For example, when three identical, close-by items are presented in the periphery, observers often report perceiving only two items. Redundancy masking has been shown to strongly depend on the spatial regularity of target arrangements: Spatially regular patterns yielded stronger redundancy masking than irregular arrangements. Here, we examined redundancy masking with regular and irregular line arrays consisting of 3-5 lines, varying color, contrast polarity or length in three different experiments. Two different feature values for each manipulation of color, contrast polarity and line length were used. This allowed us to differently group lines within the line arrays: uniform arrays, arrays with alternating lines, and arrays with subgroups of identical lines with different lines at the edge of the arrays (outer lines). The line arrays were briefly presented in the periphery. Observers reported the number of lines and indicated the feature values of each perceived line. Our results showed that there was redundancy masking in all conditions. Importantly, we found highly systematic redundancy masking patterns: The perception of stimulus edges, detecting the presence of the two feature values, and noticing their ratio remained largely intact. Redundancy-masked lines were predominantly from the center of the stimulus and from within subgroups of identical lines. These results suggest that regularity of the entire stimulus array is not mandatory for redundancy masking. Instead, redundancy masking may occur in stimulus parts that 'ungroup' from other stimulus parts. Taken together, our results showed that redundant information was compressed, but crucial information such as the edges that provide information about, for example, the size and shape of the entire stimulus remained intact. We suggest that redundancy masking is a key mechanism to compress redundant information in visual environments.

What is gloss?

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Reflective materials, such as metals, plastics and paints have diverse surface properties that give them their distinctive appearances. In everyday language, we use various terms to describe their qualities (e.g., sheen, lustre, shininess). In the material perception literature by far the most prominent of these terms is 'gloss'. Researchers investigate gloss estimation, gloss constancy and illusions of gloss. Yet, what exactly does the term 'gloss' mean? What aspects of appearance does it refer to?

Gloss is typically associated with the magnitude of specular reflectance, and experiments rarely vary more than one or two additional reflectance parameters. Yet to fully characterise reflectance requires the bidirectional reflectance distribution function (BRDF)—a high-dimensional representation of how light reflects in every direction for every incoming direction. Many aspects of the BRDF other than the overall specular reflectance could contribute to or influence our sense of 'gloss'.

Here we conducted the most comprehensive study on the impact of reflectance parameters on perceived gloss to date. Eighteen participants viewed 150 rendered movies of a rotating irregular shape with varying reflectance properties, and rated how 'glossy' each one appeared. On each trial, random values were assigned to 10 parameters of the 'Principled BSDF' shader in Blender. This allowed us to measure the relative contribution of each parameter to gloss perception.

Surprisingly, we find that the gloss ratings were dominated not by the magnitude of specular reflectance—as commonly assumed—but by the microscopic surface roughness. Over 75% of the variance in participants' responses were due to this single parameter. Rough surfaces lead to blurrier reflections, which were seen as significantly less glossy than smooth surfaces with sharp reflections. In other words, for naïve observers, 'gloss' is first and foremost related to 'distinctness-of-image gloss' rather than 'contrast gloss'.

Glare from LED illuminants of different colour temperature under simulated driving conditions at night

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LED technology is becoming increasingly prevalent in our daily lives, including on the roads at night, in the form of street lights and car headlights. Previous studies have shown that LEDs with a high correlated colour temperature can cause more discomfort glare than LEDs with a low correlated colour temperature. However, it is not yet known how this parameter affects disability glare in drivers under mesopic conditions. The main objective of this study is to analyse the influence of the spectral emission of lamps on glare during a representative night-driving task, specifically the reaction time.

Twenty young subjects participated in the study. A two-channel Maxwellian optical vision system was used to measure foveal reaction time without and with a glare presented at a temporal retinal eccentricity of 10°. A 2º stimulus with a Weber contrast of 0.1 was used, presented over a background field with two different luminances, 0.1 and 1 cd/m2, provided by a LED lamp with a correlated colour temperature of 4000 K. Glare source was produced by two LED with correlated colour temperature of 2800 and 6500 K, providing an illuminance of 50 lux.

In the glare condition, reaction time is significantly lower for the background luminance of 1 cd/m2 respect to 0.1 cd/m2, for both 2800 K ($p < 0.05$) and 6500 K ($p < 0.05$) lamps. No effect of correlated colour temperature is found on reaction time measurement for 1 cd/m2 ($p = 0.23$)..

In conclusión, our study found that young drivers experience similar glare impairment measured in terms of visual reaction time regardless of the colour temperature of the LED light source.

Identifying the principles of causal perception through visual adaptation transfer

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Recent work has found that there is a genuinely perceptual representation of 'causality' for at least some specific causal events. The prototypical example is the Michottean 'Launching' event, in which an object A moves until it is adjacent to an object B, at which point A stops and B immediately starts moving. Past work has shown that this event is subject to retinotopically-specific visual adaptation effects, and recent work has used adaptation transfer to demonstrate that adaptation to other elastic-collision-like events affects the perception of launching (e.g., 'Triggering'), but not causal events that resemble inelastic interactions (e.g., 'Entraining'). Using this adaptation transfer paradigm, here we seek to develop a principled account of what events do and do not share this underlying perceptual

representation of 'causality'. Participants saw a pre-adaptation phase of ambiguous events where A and B overlap to varying degrees between 0% and 100%. These events can be perceived as 'launch' events, as described above, or 'pass' events in which object A moves over/under B without contact. Participants then saw 400 repetitions of one of four adaptation events (between-subjects): Launching, 'Tool effect' events (in which there is a third object between A and B), 'Bursting' (in which B splits into multiple smaller objects that 'spray' forward), and 'State change' events (in which B does not move but changes color). With 75% of the preregistered sample collected, results suggest a successful replication of retinotopically-specific adaptation to launching ($p<.001$), and that 'tool effect' adaptation transfers to the perception of launching ($p<.001$). However, there is no such adaptation transfer from 'bursting' events which violate principles of object cohesion ($p=.48$), or 'state change' events which do not involve motion ($p=.07$). This suggests that the underlying perceptual representation of 'causality' that these adaptation effects capture involves motion-based elastic causal interactions between discrete, coherent objects.

Audiovisual spatial ventriloquism is reduced in musicians.

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There is growing interest in the effects of expertise on multisensory perception. Recent findings suggest that musicians may be more accurate and precise when integrating auditory and visual stimuli in the temporal domain. We investigated whether musicians also exhibit such advantages in the spatial domain. Musicians and non-musicians participated in an auditory localisation experiment that measured ventriloquism and recalibration (rapid and cumulative) using brief flashes and noise bursts as stimuli. Musicians were significantly less susceptible than non-musicians to ventriloquism, as their auditory localisation judgements were less influenced by a brief flash that was horizontally displaced by 10 degrees. However, there were no significant effects of musical training for unimodal auditory localisation or for susceptibility to rapid or cumulative recalibration. We replicated all of these results in an additional, independent experiment, and the effect of musical training on ventriloquism was large and consistent across both experiments. Our results suggest that multisensory expertise (i.e., musical training) can improve the accuracy with which observers integrate basic sensory stimuli in the spatial domain, possibly due to top-down influences on perception. Our lab is now conducting a variation of this experiment and fitting a computational model to the data (Bayesian causal inference) to formally investigate which processes account for reduced ventriloquism in musicians.

Transfer of reafference signal adaptation across smooth pursuit speeds

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Smooth pursuit eye movements decouple motion on the retina and motion in the environment. To recover motion in external coordinates, the retinal motion can be compensated by the predicted sensory consequences of the smooth pursuit eye movement. Previous research showed that the size of this pursuit-related predicted reafference signal is continuously updated, based on a direction-selective interaction between the motor command of the pursuit, and the experienced retinal motion during the eye movement. Here, we tested if this adaptation is also specific to the speed of pursuit or if it generalizes across speeds. We first replicated the previous findings – specifically, we mimicked imperfections of the reafference signal by asking subjects to execute smooth pursuit across backgrounds moving at a constant velocity (exposure trials), either in the direction of the eye movement or opposite to the direction of the eye movement. This sequence of exposure trials was occasionally interrupted by test trials in which the background velocity was determined by an adaptive staircase procedure, to estimate the point of subjective stationarity (PSS). In our results, the PSS shifted in the direction of the exposure background speed. Secondly, we investigated how the exposure to background motion during pursuit affects the perceived motion when different pursuit speeds are used for test and exposure trials. We found that the adaptation of the reafference signal transferred robustly to lower and higher pursuit speeds and was not restricted to the pursuit speed during exposure. This transfer could be explained by the broad speed tuning of direction-selective neurons, by a gain-field modulation as it has been observed for the transfer of motor adaptation or by a gain-control mechanism as it has been observed for the sensorimotor transformation in smooth pursuit.

Acknowledgments: This work was supported by "The Adaptive Mind", funded by the

Excellence Program of the Hessian Ministry of Higher Education, Science, Research

and Art

Effect of spatial context on perceived walking direction

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Observing an adaptation (temporal) context effect in our recent study on walking direction in biological motion motivated us to investigate an effect of spatial context, as contextual modulation is well described for many aspects of high-level vision (e.g., eye contact) but is relatively unexplored for walking direction. Here, we examined the spatial contextual modulation of walking direction by measuring the perceived direction of a target walker in the presence of two flanker walkers, one on each side. Experiment 1 followed a within-subjects design. Participants (N= 30) completed a spatial context task by judging the walking direction of the target walker in seven different conditions: a walker alone in the centre; a walker with two flanking walkers either intact or scrambled at a flanker deviation of ±15, ±30, or ±45 degrees. To compare spatial and temporal contextual effects within subjects, participants also completed an adaptation task in which they were asked to report whether the walking direction of a target point-light walker was to their left or right after adaptation to one of two walking directions of ±30 degrees. We found the expected repulsive effects in the adaptation task but attractive effects in the spatial context task. In Experiment 2 (N= 40), we measured the tuning of spatial contextual modulation across a wide range of flanker walking directions ranging from 15 to 165 degrees in 15-degree intervals. Our results showed significant attractive effects across a wide range of flanker walking directions with the peak effect at around 30 degrees. This study extends our understanding of the difference between spatial and temporal contextual modulation in high-level visual processing.

Second Order Chromatic Contrast Sensitivity

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The visual perception of complex stimuli can be defined by second-order stimuli considering their composition by white or pink spatial noise, contrast-modulated or luminance-modulated. In this study, we used a pink noise contrast-modulated to evaluate the chromatic red-green and blue-yellow contribution to complex texture-like spatial perception. Participants were 9 adults aged 18 to 30 years old (mean= 25; SD= 4.2). A red-green and blue-yellow heterochromatic flicker procedure was used to compensate for any luminance function. Chromatic Second-Order Contrast Sensitivity was measured for 0.5, 1.0, 2.0, 4.0 and 8.0 cpd gratings presented at a visual angle size of 4°. A correspondent chromatic pink-noise carrier had a 6° of visual angle at 60cm. Higher sensitivity values were identified for high frequencies in both Blue-Yellow stimuli (0.5cpg= 4.8/ 1.0cpg= 5.5/ 2.0cpg = 13.5/ 4.0cpg = 18.8/ 8.0cpg = 16.8.), and Red-Green (0.5cpg = 2.8/ 1.0cpg = 2.6/ 2.0cpg = 3.9/ 4.0pg = 6.5/ 8.0cpg = 6.1) gratings. Significant lower sensitivity was obtained blue-yellow grating related to red-green ($p<0.001$ for all spatial frequencies). We successfully measured second-order for chromatic stimuli for both red-green and blue-yellow color channels. Our results suggest that red-green color opponent channel has a higher contribution to texture perception than the blue-yellow channel.

Feed-forward projections from V1 to EBA sustain body visual adaptation: a ccPAS study

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Body perception can be reshaped by previous experience as documented by visual aftereffects following prolonged exposure. Here, we used a cortico-cortical paired associative stimulation (ccPAS) protocol to study the role of feed-forward and reentrant connections within the occipito-temporal cortex in body gender adaptation, whereby exposure to a distinctively female or male body makes androgynous bodies appear as more masculine or feminine, respectively. The task consisted of an Adaptation Phase, in which participants were exposed to male or female sex-typing virtual-human bodies, followed by a Test phase in which they were asked to discriminate the gender of a series of androgynous bodies. The ccpAS protocol consisted of 90 paired pulses of Transcranial Magnetic Stimulation (TMS) delivered over the left extrastriate body area (EBA) and V1 in two 15-min sessions. In one session (V1-EBA), we boosted feedforward connections by applying TMS first over V1 and then, after 20 ms, over EBA; in the other session (EBA-V1), we boosted reentrant connections by applying TMS first over EBA and then, after 20 ms, over V1. We used a within-subjects experimental design in which 34 healthy participants (18 women) underwent the male and female body exposure procedure either after V1-EBA or after EBA-V1 ccPAS, in a counterbalanced order. In both ccPAS sessions, prolonged exposure to bodies with sex-typing features biased the perception of the androgynous bodies towards the opposite gender. Crucially, these adaptation effects were boosted after V1-EBA as compared to EBA-V1 ccPAS. This study suggests that body gender adaptation rely on feed-forward cortical connectivity between V1 and body-specific cortical areas in the occipito-temporal cortex. Alterations of these pathways may underlie dysfunctional body adaptation in patients with eating disorders, which could be restored by boosting feed-forward connectivity in the occipito-temporal cortex.

Individual differences in change detection and the motion aftereffect

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We developed a covert search task with dynamic stimuli, wherein success depends on the adaptation that results from stable fixation. In one variant, 36 drifting Gabor patterns simultaneously disappear. After a brief interval, 16 new patterns are presented, one of which drifts in the direction opposite to the pattern it replaced. The participant must select this target. Unlike traditional measurements of the motion aftereffect, our 'change detection' task is virtually immune to non-perceptual biases like the subject-expectancy effect. We tested 102 observers on two versions of the change-detection task: direction reversal and orientation change. Performances in the two tasks were highly correlated ($r = 0.55$, $p = 0.0003$). When combined, the two performances were negatively correlated with fixational instability ($r = –0.4$, $p = 0.0002$). After eliminating observers with poor fixation, combined performances were used to identify the 5 strongest and 5 weakest 'change detecters'. We then assessed the motion aftereffect in these observers using a similar task, except that the 16-Gabor 'test' array was replaced by 15 static circles and one slowly drifting target. In this task, the motion aftereffect makes search difficult. Performance was compared to a baseline condition, in which the 36 Gabor patterns in the 'adapting' array did not drift. The effect of drifting adaptors proved devastating to the performances of the strongest change detecters. Its effect on 4 of the 5 weakest change detecters was marginal. In a third experiment, compared with gratings drifting in the opposite direction, gratings drifting in the same direction as adapting stimuli required more contrast for detection by all our 'good detecters'. Only 2 of our 4 'weak detecters' produced data consistent with this direction-selective elevation of contrast threshold. We conclude that poor change detection may be associated with unusually weak motion aftereffects.

Neurophysiological correlates of foveal crowding and tagging

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Introduction: Our previous studies showed that crowding also occurs in the fovea under brief presentation times. We also found that tagging reduces foveal crowding, improves sensitivity, binocular summation, and shortens the reaction time. Here we chose to use an EEG method to explore the mechanism underlying crowding and tagging and to determine whether they are related.

Methods: Ten adults with normal or corrected-to-normal vision participated in the study. EEGs were recorded from 64 passive tin electrodes (Quik-Cap). An E target (black or red) was briefly presented (30/40/50/60/80 ms) at the fovea, surrounded by a matrix (5X5) of randomly rotated E letters with one or 0.4 letter-spacing (uncrowded, crowded). The task was to identify the direction of the E target (right, left).

Results: Foveal crowding, relative to the uncrowded condition, reduces the sensitivity and the reaction time (RT), whereas tagging reduces the crowding effect, improves sensitivity, and shortens the RT. We found a significant correlation between the N1 (occipital electrodes) and P3 (frontal electrodes) components, and the proportion correct. However, no significant correlation was observed for the P1 component. Also, a significant difference was observed for the N1 amplitude between crowding and the uncrowded or tagging conditions. However, no significant difference was observed between uncrowded and tagging. The significant results for N1 were found in the occipital region only.

Conclusions: The findings that P1 is influenced by physical properties and that N1 amplitude increases when the crowding effect decreases are consistent with previous work. Our study shows that the effects of tagging reminiscent the uncrowded condition. Thus, it raises the hypothesis that there is a mutual relationship between crowding and tagging; crowding groups the elements, whereas tagging ungroups them. Also, the main region where the induced activity of crowding is measured is apparently in the occipital region.

Unveiling the foveal rod scotoma through an afterimage

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Vision under low-light conditions relies on rod receptors only. Due to the absence of rods in the fovea (rod scotoma), we do not receive sensory information in the central visual field. Strikingly, this gap in the sensory information is rarely noticed due to perceptual filling-in: The visual system interpolates information from the surround to "fill" the gap and yield a seamless percept. Here we tried to make the rod scotoma visible and measure its perceived size under different lighting conditions.

We employed a flickering background to disrupt perceptual completion: Since the filling-in mechanism lags behind the flicker, the rod scotoma became visible as a blurry, circular afterimage in the central visual field. First, the participants determined the flicker frequency at which the afterimage was most visible to them. Second, they adjusted the size of peripheral disks to match the size of the foveal afterimage at four different flicker frequencies (mean of their chosen frequencies, mean +/- 0.25 and -2 octaves). To address the role of receptor adaptation in the filling-in of the rod scotoma, we tested participants under scotopic viewing, when only rods are active and under mesopic viewing, when both rods and cones are active. Critically, in mesopic viewing we sought to stimulate selectively rods to minimize interference with cones.

Our findings indicate that a flickering background is sufficient to make the foveal rod scotoma visible, similar to the blue scotoma caused by the absence of S-cones in the foveola. Participants preferably chose flicker frequencies of about 3 Hz to perceive the scotoma. They matched peripheral disk sizes of about 1.65° to 3.25° to the scotoma, with individual differences for the different flicker frequencies.

Acknowledgments:

This work was supported by the European Research Council (ERC) under the

European Union's Horizon 2020 research and innovation programme (grant

agreement No. 101001250) and by "The Adaptive Mind", funded by the Excellence

Program of the Hessian Ministry of Higher Education, Science, Research and Art.

Investigating the Impact of Audio-Visual Training in Virtual Reality on Learning Outcomes through Multisensory Integration: An Analysis of fMRI and DTI Data

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The brain's ability to integrate information from different sensory modalities is a crucial process that allows for the modification of behaviour and enhancement of perception. Virtual reality (VR) technology provides an immersive and realistic environment to study multisensory integration. Recent studies have revealed that the brain's microstructure can undergo experience-dependent plasticity in adulthood. This study aimed to investigate the effects of an audio-visual training program utilizing VR on brain activity, microstructure, and cognitive performance.

Twenty healthy participants were recruited to complete a 30-minute daily systematic audio-visual VR training program for four weeks. Neuroimaging data, including functional magnetic resonance imaging (fMRI) and diffusion tensor imaging (DTI), as well as performance data and laboratory tests, were collected at baseline, after two and four weeks of training, and four weeks post-training.

Repeated measure ANOVA analysis of the behavioural data revealed significant improvements in task completion time and scores over time. Paired t-tests were conducted on the fMRI and DTI data to compare pre- and post-training results. The results showed increased functional activation in multisensory brain regions involved in early-stage audio-visual processing during the audio-visual fMRI task. The DTI data revealed changes in microstructural indices in the optic radiation and superior longitudinal fasciculus II, which are key white matter tracts involved in eye movement, multisensory integration, and spatial attention.

The study provides new insights into the neural mechanisms underlying multisensory integration in virtual environments, using a combination of neuroimaging techniques. Incorporating spatial auditory cues into voluntary visual training in VR led to augmented brain activation and microstructural changes in multisensory integration, resulting in measurable performance gains that apply to involuntary and visual search conditions. VR-based multisensory training is a promising approach for enhancing cognitive function and a valuable tool in rehabilitation settings.

Systematic Bias in Object Location Memory Across Perspectives: Evidence from Immersive Virtual Reality

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Place recognition is crucial for orientation and requires memory of object locations and retrieval from different perspectives. In a series of studies using 2D images, we observed a

systematic bias in object location memory across different perspectives with participants systematically biassing their location estimates in the direction of the shift. This bias was not influenced by memory distortions and instead we showed that it is primarily driven by camera translations instead of rotations. What remains unclear, is whether this bias rises due to distortions introduced due to presentation of 3D spatial information on 2D screens or if it generalises to object location memory across different perspectives in 3D environments. To investigate this, we utilised immersive virtual reality and had participants memorise an object's location in a virtual room. Following a passive teleportation to a new location, participants were asked to place the object back in its original location. We repeated this task in a fixed head and free viewing condition. Preliminary results indicate that the same bias reported earlier in studies using 2D scenes is observed in both conditions. Specifically, after a perspective shift via teleportation, participants tended to estimate object location in the direction of the teleportation. We suggest that this bias arises from participants anchoring their location estimates to the initial egocentric vector

to the object experienced during encoding. This bias's presence across 2D images and immersive 3D environments indicates that in the absence of self-motion information, needed to support spatial updating, humans may rely on heuristics, such as anchor and adjustment, to resolve spatial perspective shifts.

Facial expression recognition modulated by forward and backward steps in virtual reality

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Humans communicate with each other using facial expressions and body actions, with both influencing each other. For example, our body actions change based on how we interpret the other person's facial expressions. Approach-avoidance behaviors, such as steps forward or backward, are influenced by facial expression recognition. These behaviors may result from biological instincts that induce approaching benefits (e.g., foods) and avoidance of harm (e.g., predators). Thus, we conducted psychophysical experiments to demonstrate a reverse causal relationship if facial expression recognition is changed by approach-avoidance behaviors. The facial expressions of a 3D face stimulus located on a virtual reality space were varied in seven steps, from happy to angry in Experiment 1 and from happy to fearful in Experiment 2. Using a head-mounted display, participants performed one of the following behaviors in front of the face stimulus; the participant 1) approaches (one meter forward), 2) avoids (one meter backward) 3) is approached, or 4) is avoided by the 3D model. In each experiment. participants chose the facial expression from two emotions shortly after performing the behavior. Experiment 1 showed that participants recognized the face as angrier when they avoided it rather than when it avoided them. This suggests that avoidance promotes the recognition of anger, which is a reverse causal relationship to "anger promotes avoidance", reported in previous studies. Experiment 2 showed that participants recognized the face as happy when approaching and fearful when avoiding, regardless of who performed the action. Overall, participants tended to recognize facial expressions as positive (happy) when approaching and negative (angry and fearful) when avoiding. These findings imply that body actions trigger a regulation of facial expressions to efficiently observe the outside world. We suggest that this tendency was created through unconscious learning, where facial expression recognition changes approach-avoidance behaviors.

Recording fixation onset ERPs in virtual reality

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Decades of traditional laboratory settings have left an open space for the question: How would the complexity of real-life scenarios transform the current state of results? Virtual reality lends itself ideally to investigating free viewing and free exploration behavior in situations of varying complexity. An essential aspect of such a study is accurately identifying and classifying eye movements recorded in virtual reality. This becomes challenging but important when dealing with time-sensitive data such as EEG, particularly for ERP analysis, where the exact onset is crucial. Using a version of the MAD saccade classification algorithm (Voloh et al., 2019) adjusted to fit three-dimensional data (Keshava et al., 2021), we classified eye-tracking data recorded during participants' free exploration of a virtual scene while EEG data was recorded. Two different data segmentation algorithms were compared to deal with varying noise levels. The distribution of event durations, the velocity distributions before and after gaze onset, and the saccade vectors indicate that we can classify our continuous, free-exploration data into gazes and saccades. A high mean correlation coefficient of individual trials to the average ERP and a homogeneous distribution of the highest velocity samples before gaze onset indicate that dealing with varying noise levels across a long recording can be best achieved using predefined intervals of ten seconds. Based on the eye-tracking data and the suitability of applying it to EEG data, we conclude that it is possible to combine EEG and eye-tracking in virtual reality in free exploration studies using the adjusted velocity-based classification algorithm.

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Depth Cues Reduction and Perception of Audiovisual Synchrony in Virtual Reality

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Audiovisual cues assist us with the interpretation of our surroundings. They might vary in propagation time due to disparate delay, though we still can combine them through

multisensory integration. Although the delay differs with distance, most events are still perceived as synchronous. One explanation is the existence of the distance compensation mechanism for synchrony judgments, but the role depth cues play is still a matter of debate.

Our study aims to investigate the effect of depth cues reduction on the effect of distance on audiovisual synchrony perception using a virtual reality environment. We conducted two separate within-subject design experiments in an indoor virtual reality environment, where we compared degraded texture with a non-degraded texture between groups and the simplified scene (reduction of objects present in the scene) with the non-simplified scene between groups.

The first experiment investigated the effect of texture degradation, and the second experiment investigated the effect of scene complexity. Each participant was tested for the egocentric distance perception through a verbal judgement task and for the effect of distance on audiovisual synchrony perception through a synchrony judgment task (audio first, synchronous, video first) with 11 stimulus onset asynchronies. The tasks were performed in a virtual factory hall, which consisted of six distances from 5 to 30 meters and an audiovisual stimulus represented by the falling cardboard box hitting the conveyor belt.

Results showed a strong underestimation of distance and a small but significant distance compensation effect. These effects were the same irrespective of whether texture was degraded, the number of objects reduced or none of the above. The results contradict previous studies claiming that the distance compensation mechanism might be affected by the availability of depth cues information.

Teleporting impairs scene recognition in virtual environments.

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Recognizing a scene from a new standpoint relies on spatial updating, i.e., the process of keeping track of how spatial information changes while moving in the environment. Spatial updating is believed to take place on-line and effortlessly during physical movement, but off-line and deliberately when the movement is imagined or simulated. When it comes to movement in virtual environments, one can also move with teleporting, i.e., by pointing to a specific location and moving there instantaneously at the press or release of a button. Teleporting lies in-between physical and imagined/simulated movement as it involves some but different idiothetic information that is present with physical movement and which may be essential for spatial updating. Based on this, the goal of the present study was to examine if movement by teleporting in virtual environments affects the ability to recognize a spatial scene from a new viewpoint. Participants carried out a scene recognition task in which they first studied a layout of objects on a circular table in a virtual reality room and then, after a delay period, indicated if the scene had changed. During the delay period, participants moved to a new standpoint around the table with physical movement or teleporting or walk in place. Results revealed that recognition performance was slower and less accurate with teleporting compared to physical movement but better to walk in place. Teleporting's performance lay in between the performance of physical movement and walk in place. Although walk in place incorporates physical movement owing to leg movement, teleporting outperformed but was not as effective as physical movement. Overall, these findings show that scene recognition from a novel viewpoint is impaired when moving with teleporting. We discuss the implications of these findings for spatial cognition and for the development of immersive applications.

Stride length decreases during overground walking while wearing a head mounted display

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Modern virtual reality (VR) technology has enabled scientists to investigate the influence of vision on human behaviour. Many studies showed how immersion into a virtual environment (VE) can produce behaviours comparable to the real world. With head mounted displays (HMD) movement experiments are getting more convenient. While some papers evaluate the possible benefits of VEs to patients it is still unclear how the use of a VR changes the gait parameters. Different strategies have been described regarding the adaptation of stride length when using VR. Here we aim to deepen our understanding in these mechanisms. We expect an increased level of uncertainty in the participants while wearing an HMD. This motivates our hypothesis that stride length will decrease when walking in VR. We collected data from n = 14 participants (7 female, 7 male) between 19 and 49 years of age (mean = 24) which ranged from 164 cm to 197 cm in body height (mean = 173.6 cm) and from 57 kg to 89 kg of body weight (mean = 68.2 kg). Each participant performed 10 walking trials with and 10 trials without a HMD. The HMD (HTC Vive Eye Pro) displayed a neutral environment featuring a meadow walkway in a natural surroundings. Motion data were collected using a 12 camera marker based motion capture system (Qualisys Oqus). Our analysis shows

that the stride length decreases significantly while wearing a HMD ($t(263) = 9.72$, $p < 0.001$***, mean decrease = 9.42%). This change in human gait during overground walking in VR supports our hypothesis. Results of VR related gait studies may not be exactly transferable to real world walking. It needs further investigation if longer adaptation times would be required.

Modulation of Postural Control and Somatosensory Processing via Predictability in a Virtual Moving Room

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Predictive processes shape perception and action. For instance, when interacting with worlds of predictable dynamics, humans exhibit anticipatory movement adjustments and downweigh sensory consequences of the movement on the moving effector. Here, we investigated how the predictability of visual perturbations influences postural adjustments and tactile sampling prior and in reaction to the perturbation.

Participants stood on a force plate and were immersed in a structured virtual room using a head-mounted display. A vibrotactile stimulation device was attached to their right calf muscle, through which we probed tactile perception. Participants faced a wall and were virtually moved 5 m toward it with a constant velocity of 3 m/s eliciting vection. This perturbation happened immediately after a visual countdown (predictable) or unexpectedly, without a countdown (unpredictable). A brief (50 ms) vibrotactile stimulus was presented either well-before, just-before, or right-after the onset of the perturbation. We presented different stimulus intensities and estimated tactile detection thresholds for each condition and participant. Anticipatory and reactive postural responses were determined for the periods before and after the perturbation onset, respectively.

As expected, the center of pressure, as well as head kinematics in the anterior-posterior direction were systematically greater in anticipation of the predictable than unpredictable perturbation. This stronger anticipatory component during the predictable perturbations came also with a stronger and earlier reactive component compared to unpredictable perturbations. Despite the modulations in motor behavior, tactile detection thresholds appear not to differ in the various conditions.

These results suggest that humans can successfully counteract visual perturbations, with stronger predictive and reactive components when perturbations are predictable. However, modulations in associated sensory processing seem to be less sensitive.

The type of interaction with virtual environment influences on presence effect

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The immersion in virtual reality (VR) is mostly provided by visual perception. Although the problem of presence effect (PE) extension is linked with the mechanisms of visual percept construction during different ways of interaction with VR. One of the measurement tools to assess the effectiveness of VR is the presence effect (PE). The aim of this research was to study the expression of PE depending on the type of interaction with the stimulation in VR. 60 subjects took part in the experiment (51 women and 9 men aged from 17 to 23). Participants were offered VR learning with two different types of interaction with the virtual environment. Stimulation was a colorful and exciting educational platform for learning chemistry. The VR environment was presented using a VR Headset HTC Vive Pro. PE expression was estimated after each immersion using ITC-Sense of Presence inventory (Lessiter et al., 2001). Sample were divided into two groups: interaction without instruction; interaction with clear instruction. The results showed that PE was significantly higher in “instruction group”. The differences were obtained in scales "Sense of Physical Space " ($Z=-4.245$, $p<0.05$), Engagement " ($Z=-3.395$, $p<0.05$) and "Ecological Validity" ($Z=-3.447$, $p=<0.05$). Thus it was demonstrated that each component of the PE is determined by the type of interaction with VR. Cognitive load is considered as a linking mechanism between the received visual information in VR and the way of user interaction. This study was supported by grant Russian Science Foundation №19-18-00474.

Vertical vergence and screen alignment with see-through head-mounted displays

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In head-mounted-displays, the visual scene is rendered assuming accurate knowledge of the 3D positions of the eyes, screens, and scene objects. However, these quantities are generally subject to positional and measurement errors, resulting in misalignment of the rendered images projected to each eye. In virtual reality (VR) setups, the user is exposed to a single (virtual) environment that is subject to the same misalignment over the entire field-of-view. Previous studies have documented that misalignments in scene rendering for VR impact user comfort

negatively, inducing symptoms like eye strain and nausea. The main goal of this work was to design and test methodologies for investigating the effects of vertical misalignment in see-through Augmented Reality (AR), where two conflicting environments coexist. One environment corresponds to the real world (background), which by definition forms “aligned” images on the retinas. The other environment corresponds to the augmented content (foreground) and might be subject to misalignments. To ensure complete controllability over the augmented and real contents and arcmin accuracy, we used a standard 3D screen with shutter glasses. Participants were involved in an engaging visual search task while being exposed to different values of vertical misalignment in the foreground during different sessions. At each session, we monitored eye alignment and evaluated discomfort symptoms with a purpose-designed questionnaire. In agreement with previous studies focusing on VR, results showed an increasing level of discomfort with increasing vertical screen misalignment. However, the sensitivity of each participant varied, both in terms of perceived discomfort and misalignment tolerance. The measured eye posture indicated that the compensation for misalignment is roughly equally shared by the sensory (binocular fusion) and the motor (vertical vergence) components of binocular vision. The proposed approach aims at providing guidelines for investigating discomfort in Augmented Reality.