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41st European Conference on Visual Perception (ECVP) 2018 Trieste

Welcome Address

The 41st European Conference on Visual Perception (ECVP) took place in Trieste (Italy), from August 26 to 30, 2018. This edition was dedicated to the memory of our esteemed colleague and friend Tom Troscianko, with an emotional Memorial lecture in his honour held by Peter Thompson during the opening ceremony.

The conference saw the participation of over 900 fellow vision scientists coming from all around the world; the vast majority of them actively participated, allowing us to offer an outstanding scientific program. In particular, we hosted almost 300 oral presentations in 21 symposia and 21 talk sessions, and more than 500 posters during the innovative 'Poster day'. Among symposia, there were two special ones: the European Symposium on Perception and Action in Sport (ESPAS), gathering the most influential researchers in the field, and Perceptual Structures – A Festschrift for Michael Kubovy, celebrating his retirement. As concerns keynotes, the Perception lecture was held by Dejan Todorović, while the Rank Prize lecture was held by Branka Spehar; moreover, in the program we also included the Kanizsa lecture, held by Walter Gerbino. Finally, we respected the tradition of the Illusion night, this year entitled "Un mare di illusioni" as it took place by the sea.

To conclude, we sincerely thank all the volunteers, whose contribution was fundamental for the success of the conference.

The ECVP 2018 organising committee

Tiziano Agostini, Paolo Bernardis, Carlo Fantoni, Alessandra Galmonte, Mauro Murgia and Fabrizio Sors

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MOBILE EYE TRACKING – WHAT CAN WE LEARN FROM REAL WORLD EXPERIMENTS?

Szonya Durant[1], Tim Holmes[2] and Johannes Zanker[1]
[1]Department of Psychology, Royal Holloway University of London, UK
[2]Tobii Pro Insight, UK

Mobile eye tracking offers great potential to transform vision science. Lightweight wearable eye-tracking glasses can sample the gaze position at 200 Hz and accurately locate gaze within a high-definition recording of the scene as viewed by moving observers. Mapping gaze data to regions and objects of interest is becoming easier with advanced image-processing algorithms. Mobile eye tracking can provide valuable insight outside the laboratory, enabling us to observe behaviour in a wide range of contexts, including workplaces, art galleries, driving, sports, social interaction, or exploring novel environments. This new direction of research fosters genuine interaction between academic research and industry.

From Eyecups to Teacups: The Development of and Insights From Mobile Eye Trackers

Benjamin Tatler
School of Psychology, University of Aberdeen, UK

If our goal is to understand perception and cognition, then we must remember that these processes are part of a larger organism that interacts with the world around it. The need to study eye movements during natural behaviour has long been recognised. Mobile eye trackers were developed in the 1950s but were too bulky for many situations. It was not until the 1990s that mobile eye tracking began to assume a prominent role in research. The now-widespread use of mobile eye tracking owes a lot to the pioneering work of Land, Hayhoe and Ballard, who studied eye movements in a range of activities including driving, tea making and ball sports. Mobile eye trackers have underpinned key theoretical advances in the field. It is now clear that any attempt to simplify a behaviour to make it easier to control and study experimentally can disrupt the normal use of gaze in that behaviour. I will discuss early steps in mobile eye tracking and the theoretical advances that have emerged from their use.

Eye Movements During Face-to-Face Communication: A Cross-Cultural Comparison

Jennifer Haensel
Department of Psychological Scienes, Birkbeck, University of London, UK

Previous studies examining cultural differences in face scanning are restricted to screen-based paradigms, which lack the visual complexity and social presence of real-world conditions. Using head-mounted eye tracking, we compared scanning strategies of British and Japanese adults during dyadic interactions. Although both groups showed more face directed gaze when listening than when speaking, British observers fixated faces longer. Contrary to screen-based findings, eye contact was shorter and less frequent, and the notion of gaze avoidance in East Asians could not be supported. We also developed semi-automatic tools to map face regions and gaze points into a spatially sensitive, normalised space. Initial results replicate existing findings, revealing clustered gaze in the face centre in Japanese observers and distributed gaze in British participants. Overall, the results show – using novel data-processing methods for mobile eye-trackers – cultural differences in naturalistic face scanning.

Mobile Eye Tracking in Landscape Architecture – Being an Invisible Companion

Christian Nollen and Dirk Junker
Faculty of Agricultural Sciences and Landscape Architecture, Osnabrück University of Applied Sciences, Germany

There are three reasons why mobile eye tracking are rarely used to study landscape architectural of open spaces: it is not a well-known application in this field, it is demanding and time-consuming, and the results are not seen as scientifically valid. However, following extensive testing of the feasibility of mobile eye tracking in open spaces at icons of garden arts such as Stourhead landscape garden and the baroque Grosser Garten, we can confirm its great potential and value for qualitative interaction analyses. Pioneering results are shown via the trial method termed *Common Shared Experience* and these provide the insight that the naturalness of subject and object outranks controllable conditions. Rather than quantitative fixation analyses, the possibility to empathize with the subjects' experience is key. Being able to see and understand what catches one's eye and the response to this will be a guide to better design.

Eye Movements and Aesthetic Experience: From the Lab to the Gallery, to Virtual Reality (VR)

Johannes Zanker
Department of Psychology, Royal Holloway University of London, UK

The study of eye movements, together with Psychophysics, is at the heart of empirical aesthetics. With the advent of mobile eye tracking, and the development of light-weight, non-intrusive glasses, new opportunities emerge to investigate aesthetic experience outside the laboratory and study the interaction of viewers with original art work in their real-world context – the gallery. From a growing range of such studies, I will focus on a large-scale experiment at the 'Abstract Expressionism' exhibition at the Royal Academy London, where we recorded eye movements of 24 visitors exploring two large milestones paintings by Jackson Pollock. The promise, technical challenges and some initial experimental results will be discussed together with the development of new methods to analyse this rich data set. This will lead to the introduction of a novel approach to combine experimental manipulation of aesthetic experience with the recording of eye movements in VR environments.

THE NEURAL CODES THAT SUPPORT VISUAL WORKING MEMORY REPRESENTATION

Rosanne Rademaker
Department of Psychology, UCSD, CA, USA

Visual working memory (VWM) can be considered the fabric of cognition – binding information from moment to moment and allowing the proliferation of information in support of behavioral goals. What are the neural codes supporting VWM? Early monkey neurophysiology work emphasized sustained firing of single neurons in association cortices as a mechanism for short-term maintenance. More recent neuroimaging work in humans revealed that VWM contents are decodable from blood oxygenation level-dependent signals recorded in early sensory cortices. These apparently disparate observations have brought about a still unresolved controversy. In this symposium, we bring together researchers from human neuroimaging, monkey neurophysiology, and computational modeling to critically examine recent evidence regarding the how, why, and where of neural codes supporting VWM in the primate brain. We will discuss the possible format of these neural codes, and how such codes form the basis of stable mnemonic representations.

Simultaneous Representation of Mnemonic and Sensory Information in Human Visual Cortex

Rosanne Rademaker, Chaipat Chunharas and John Serences
Department of Psychology, UCSD, CA, USA

Traversing everyday sensory environments often requires representing information about relevant features or objects in memory while simultaneously processing new sensory inputs. Although early visual cortex demonstrates persistent modulation of feature-selective neural responses during visual working memory (VWM) maintenance, recent work suggests that visual cortex can only represent the contents of memory or the characteristics of new sensory inputs, but not both. Here, we demonstrate that response patterns in visual cortex can concurrently represent information about the contents of VWM alongside the specific features of new sensory inputs. This region-level multiplexing capacity in classic sensory areas may support a local circuit for computing a 'match' signal between behaviorally relevant but no longer visible features and new sensory stimuli.

The Role of Neurons Across Visual-Processing Stages in Working Memory

Diego Mendoza-Halliday[1], Santiago Torres[2], Robert Desimone[1] and Julio Martinez-Trujillo[3]
[1]McGovern Institute for Brain Research, MIT, MA, USA
[2]Department of Physiology, McGill University, Canada
[3]Robarts Research Institute, Western University, Canada

Contradictory evidence for the role of various cortical areas in visual working memory (VWM) has led to a major controversy. Based on our neurophysiological and optogenetic data in monkeys, we propose several principles to solve this controversy: Sustained activity coding VWM emerges in visual association areas immediately downstream of early visual cortex; it is also present—and necessary—in the lateral prefrontal cortex (LPFC), as optogenetic LPFC inhibition impairs VWM. Early visual areas exclusively encode sensory inputs, yet their excitability may be modulated by high-level areas coding VWM, putatively influencing sensory processing. The cortical architecture in areas coding VWM is characterized by more excitatory and less inhibitory neurons than in early sensory areas. Our results suggest that VWM is neither ubiquitous nor exclusive to high-level executive areas; instead, it is carried out by a distributed—yet finite—network of functionally specialized areas/neurons.

Coding of Visuo-Spatial Working Memory by Neuronal Ensembles in Primate Lateral Prefrontal Cortex

Julio Martinez-Trujillo and Matthew Leavitt
Department of Physiology and Pharmacology, University of Western Ontario, Canada

Working memory is the ability to remember task relevant information for short time periods. Previous studies have shown that the neural correlate of working memory is the sustained activity of neurons representing the remembered information in different brain areas. Here, we investigate the neural correlates of visuo-spatial working memory in the lateral prefrontal cortex (LPFC) of primates. We record the responses of single neurons and ensembles in the LPFC of macaques during a spatial working memory task that required the animals to remember the spatial location of a stimulus during a certain period and make a saccade to that location. We found that neuronal ensembles encode more information than the average information encoded by single neurons. Moreover, we demonstrated that relatively small neuronal ensembles, sometimes including untuned neurons, maximize the encoded information. The latter was due to the effect of noise correlations positively contributing to information coding.

When Working Memory Is Stored in Sensory Areas and When It Is Not

Thomas Christophel
BCCN Berlin, Charité Universitätmedizin, Germany

There is evidence for working memory storage in a widespread network of cortical areas ranging from early visual to prefrontal cortices. Recent null results have brought into question the role of early visual cortex involvement, suggesting previous findings were merely epiphenomenal. Here, we consider an alternative explanation: Working memory contents can be reallocated to different cortical sites in the service of behavioral goals. First, we show that visual stimuli that are more easily memorized using a verbal or invariant code are reallocated to anterior regions (abstraction-induced reallocation). Second, we show that the attentional prioritization of a remembered item can degrade the representation of an unattended item in sensory cortex, which benefits recall of the attended item (interference-induced reallocation). These findings reconcile theoretical views that either emphasize sensory recruitment or suggest a central role for parietal and frontal stores during working memory.

Synaptic and Network Mechanisms of Serial Biases in Spatial Working Memory

Albert Compte[1], Joao Barbosa[1], Heike Stein[1], Diego Lozano-Soldevilla[1] and Christos Constantinidis[2]
[1]Department of Experimental and Clinical Neurosciences, IDIBAPS, Spain
[2]Department of Neurobiology and Anatomy, Wake Forest University School of Medicine, NC, USA

Serial biases in parametric responses during visuospatial delayed response tasks provide the opportunity to study the mechanisms of different memory processes, at different temporal scales. We addressed the neural basis of interference between successive trials by analyzing behavioral and electrophysiological data from monkeys and humans performing these tasks. Our analyses show that brain signals represent memorized stimuli robustly during memory delays, but not in the intertrial periods. However, stimulus representations reemerge in electrophysiological activity just prior to the new trial, suggesting the interaction between electrically active and inactive representations of memorized information. We specified this hypothesis mechanistically in a bump-attractor computational model that included short-term synaptic plasticity. The model matched the physiology and psychophysics and derived predictions that we validated in human behavioral experiments and in monkey physiology.

STRANGE BLUES: MELANOPSIN-MEDIATED PERCEPTION OF SPACE, COLOUR AND BRIGHTNESS

Manuel Spitschan
Department of Experimental Psychology, University of Oxford, UK

Twenty years ago, the photopigment melanopsin was discovered in the skin, brain and eyes of frogs. In humans, it exists only in the intrinsically photosensitive retinal ganglion cells (ipRGCs) where it modulates the pupil and mediates light-evoked responses affecting sleep and the biological clock. The role of the melanopsin pigment in mediating our perception of the world in its colourful and dynamic fine spatial detail is less clear. Recent animal work indicates not only that ipRGCs are endowed with an ability to encode spatial detail but that this information also gets transmitted to afferent targets beyond the retina. A role for melanopsin in visual perception goes against the orthodoxy that cones and rods are the only photosensitive elements in the retina. The goal of this symposium is to bring together researchers interested in melanopsin contributions to visual perception to discuss recent scientific developments.

Integration of Melanopsin Signals Into Visual Pathways

Pablo A. Barrionuevo[1] and Dingcai Cao[2]
[1]ILAV, CONICET – UNT, Argentina
[2]Department of Ophthalmology and Visual Sciences, University of Illinois at Chicago, IL, USA

Anatomical studies showed that melanopsin-containing intrinsically photosensitive retinal ganglion cells (ipRGCs) project to the lateral geniculate nucleus (LGN); however, how melanopsin photopigment activation integrates into the magnocellular (MC), parvocellular (PC) and koniocellular (KC) pathways is not understood. To study this, we have implemented three approaches, including natural image statistics analysis, pupillary recordings and psychophysical testing. Principal component analysis of nine hyperspectral images revealed that optimal combinations of photoreceptors involved intrusion of melanopsin signals in the three postreceptoral pathways. Flickering pupillary recordings (1 Hz) showed melanopsin activation combines linearly in the MC and KC pathways but non-linearly in the PC pathway. Psychophysical testing showed melanopsin modulations of sinusoidal temporal contrast sensitivity, especially of the MC pathway at 3 Hz for 2,000 Td. Our results demonstrated that all three visual pathways are affected by melanopsin activation but in different fashion and extent.

Characterising Melanopsin Photoreception in Humans: Why, How, and With Which Degree of Precision and Accuracy?

Manuel Spitschan
Department of Experimental Psychology, University of Oxford, UK

The photopigment melanopsin is expressed in a subset of retinal ganglion cells, rendering them intrinsically photosensitive in the absence of cone and rod input. Because cones, rods and melanopsin have broad and overlapping spectral sensitivities, no monochromatic or narrowband light allows for the selective study of melanopsin-mediated responses, and psychophysical and physiological output will be nonspecific. The method of silent substitution has emerged as a powerful research tool to study the role of melanopsin in visual functions, including the pupillary light reflex, psychophysical detection and discrimination of brightness, and neuroendocrine outputs. Here, I will review (a) silent substitution and its physical realisation using spectrally tuneable or LED-based multi-primary light sources, (b) challenges in isolating melanopsin function (individual differences, retinal inhomogeneities, cones in the shadow of the retinal blood vessels) and (c) emerging areas of investigation.

Melanopsin Mediated Photoreception in Humans

Andrew J. Zele
Visual Science Laboratory, School of Optometry and Vision Science and Institute of Health and Biomedical Innovation, Queensland University of Technology, Australia

It is evident that melanopsin interacts with rods and cones to influence vision and non-visual functions. Our post-illumination pupil response (PIPR) spectral sensitivity data show rhodopsin and melanopsin contributions to the early redilation phase and thereafter by melanopsin. PIPR amplitudes are phase locked to circadian rhythms and vary with retinal eccentricity as per the melanopsin ganglion cell density. Our clinical studies signify the PIPR as a biomarker of melanopsin dysfunction in age-related macular degeneration, glaucoma and diabetes, with this dysfunction contributing to circadian and sleep disorders. By controlling the excitation of melanopsin, rhodopsin and the three cone opsins after optical corrections in human eyes and attenuating penumbral cones, we show melanopsin contributions to vision match an S-off L + M-on receptive field property; melanopsin photoreception has lower sensitivity than canonical processes, temporal resolution to $\sim$5 Hz and interacts with cones to alter colour and brightness.

Human Visual Performance Based on Cone and Melanopsin Photoreceptors

Sei-Ichi Tsujimura
Department of Information Science and Biomedical Engineering, Kagoshima University, Japan

We designed the stimulation system that enables independent stimulation of cone and melanopsin photoreceptors. The two test stimuli were used: one varying cone alone without change in stimulation of melanopsin (Cone stimulus) and the other varying radiant flux of the stimuli without change in spectral composition (Lightflux stimulus) and measured temporal contrast sensitivity. Retinal illuminance for the test field was approximately 4.0 log photopic troland. Eleven subjects participated in the experiment. It was found consistently for all subjects that the sensitivity to Lightflux stimulus at the frequencies between 0.25 Hz and 1 Hz was significantly lower than that to the cone stimulus ($p = .002$), suggesting that there is an inhibition between cone and melanopsin signals. These results suggested that there is a temporal difference between cone and melanopsin photoreceptors that causes the apparent inhibition.

Does Blue Light Wake You Up or Make You Down? Visual and Non-Visual Effects of Varying Light Spectra

Anya Hurlbert[1], Gaurav Gupta[1], Yvonne Lai[1], Naomi Gross[1], Stacey Aston[2], Brad Pearce[1] and Kirstie Anderson[1]
[1]Institute of Neuroscience, Newcastle University, UK
[2]Department of Psychology, Durham University, UK

Light not only enables humans to see via the classical visual pathway but also affects alertness, mood and biological rhythms, via the non-visual pathway originating in the melanopsin-containing retinal ganglion cells (mRGCs). To disentangle contributions of the two pathways to light-influenced behaviour, we selectively modulate the melanopic and photopic irradiance and visual chromaticity of light from spectrally tuneable multi-channel LED sources, in an immersive, naturalistic setting. We find that, in the evening, lights with high melanopic irradiance ('white' or 'blue') suppress melatonin levels and sleepiness, but reduce performance on visual attention tasks, and worsen mood, relative to lights of low melanopic irradiance and high photopic irradiance ('amber'). Tuning light spectra to modulate the way people see and feel – depending on time of day and task at hand – is now achievable, but understanding visual and non-visual interactions remains elusive.

Redesigning Visual Displays to Understand Melanopsin's Contribution to Vision

Annette Allen
Faculty of Biology, Medicine and Health, University of Manchester, UK

Intrinsically photosensitive retinal ganglion cells (ipRGCs) respond to light, thanks to their expression of melanopsin, and are specialised to encode long-term light intensity in order to regulate reflex light responses (entraining the circadian clock, regulating pupil size). ipRGCs also form part of the primary visual pathway, implying that melanopsin can contribute to pattern vision. To explore this hypothesis, we developed a display comprised of five spectral channels that can regulate the activity of melanopsin independently of cones in space and time. We first used this display to map the spatial/temporal contribution of melanopsin, alongside cones, to electrophysiological activity in the mouse visual thalamus. We also explored how melanopsin also regulates visual perception, using a display optimised for the human visual system. Together, our data reveal that melanopsin's contribution to vision is distinct from cones and serves to extend the spatiotemporal range of pattern vision.

ROLE OF ARTICULATION IN PERCEPTION OF SURFACE LIGHTNESS

Alan Gilchrist
Department of Psychology, Rutgers University, NJ, USA

When David Katz, in his pioneering 1930s work, asked subjects to match the reflectance of a disk in shadow with that of a disk in bright illumination, he found only modest constancy. But when he and Burzlaff replaced each single disk with a tableau of 48 shades, they found almost 100% constancy. Since its re-discovery in the 1990s, a large body of data has confirmed the powerful effect of articulation for lightness and color. Yet its impact is still not reflected in theory. Although Katz claimed that articulation strengthens constancy, other work has shown that it makes lightness illusions stronger, implying less constancy. A reconciliation of these results is implicit in the Kardos theory that lightness is codetermined by both local and foreign frames of reference, with framework weighting determined mainly by degree of articulation. A panel of experts in surface color and lightness will discuss both recent work on, and theoretical implications of, articulation.

Strong Impact of Articulation on Lightness: Theoretical Implications

Alan Gilchrist
Department of Psychology, Rutgers University, NJ, USA

Articulation, defined as the number of distinct patches within a field of illumination, exerts a powerful effect on lightness, rivaling that of surround luminance and the role of depth perception. Katz, who first reported strong articulation effects concluded that greater articulation produces greater constancy. Kardos, in his co-determination theory of constancy failures, went further, arguing that greater articulation within the relevant field of a target gives it greater weight against the influence of the foreign field. Recent experiments show that when articulation is introduced into lightness illusions, such as simultaneous contrast, or White's illusion, constancy is reduced, not strengthened, supporting Kardos. These findings pose a strong challenge to theories based on lateral inhibition, spatial filtering, inverse optics, and unconscious inference.

Effects of Articulation on Lightness Constancy

Sunčica Zdravković[1,2]
[1]Department of Psychology, University of Novi Sad, Serbia
[2]Department of Psychology, University of Belgrade, Serbia

Gelb demonstrated a dramatic failure of constancy when a single black surface, suspended in midair within a spotlight, appeared white. Adding patches to the spotlight, however, increases constancy. Constancy improves (but is still bad) when a row of 5 squares (ranging from black to white) is suspended in midair within the spotlight but approaches 100% with 25 squares. We found half that much improvement in constancy when a second group of 25 patches was suspended nearby under an equal spotlight. Given that articulation improves constancy only when the increase takes place within the same illumination framework, this suggests that the two groups function partially as a single framework even while not spatially adjacent. Constancy decreased as the highest luminance, proximity, depth, or planarity of the second group deviated from that of the five squares, suggesting that these are grouping factors that cause nonadjacent regions to be perceived as parts of a single framework.

Changing Lights on Changing Scenes: Dynamic Articulation Disturbs Illumination Estimation

Anya Hurlbert
Institute of Neuroscience, Newcastle University, UK

Colour constancy is the perceptual stability of surface colour under changing illumination. Perfect constancy would dictate no discernible change in surface colour appearance as the illumination changes. The just-detectable change in appearance under an illumination change expressed as an illumination chromaticity discrimination threshold, thus gives a quantitative measure of colour constancy. Illumination discrimination thresholds are lower for uniform surfaces than for heterochromatic Mondrian scenes, supporting Katz's claim that articulation strengthens constancy. Disrupting the spatial configuration of surfaces, while keeping the reflectance set constant, makes it harder but not impossible to discriminate a concomitant illumination change. These findings suggest that (a) global scene average chromaticity is not sufficient to drive illumination estimation and (b) the role of articulation in colour constancy depends on the temporal stability of the spatial configuration.

Sampling Surfaces to Estimate Scene Illumination Colour

David Foster
Department of Electrical and Electronic Engineering, University of Manchester, UK

In theory how many surfaces should a scene contain for observers to estimate the illumination, and thereby surface colour? This question was addressed here by computational simulation. Surfaces were sampled randomly from each of 50 hyperspectral images of outdoor scenes under different daylight illuminants, and each illuminant was then estimated from each scene's reflected light: the more accurate the estimate, the better the colour constancy. The estimator was the space-average scene colour, which observers prefer in some illuminant discriminations (the "grey world" assumption). Consistent with Katz's findings on articulation, the accuracy of these estimates generally increased with sample size but only up to a few tens of surfaces. With larger samples, surfaces giving maximum cone excitations provided more accurate estimates ("white patch" assumptions). Observers' preferences for illuminant estimators may be suboptimal except for scenes with limited numbers of surfaces.

Articulation and Lightness Illusions

Elias Economou
Department of Psychology, University of Crete

Several factors have been employed in explaining lightness illusions, including retinotopic, geometric, and organizational parameters. Articulation is one of the largest factors contributing to the apparent strength of an illusion. From Adelson's checker—shadow and corrugated plaid to White's illusion, increased articulation seems to result in larger errors. However, there is little understanding as to how exactly articulation strengthens lightness illusions. Here, we present some new experiments designed to explore in more detail the contribution of articulation to illusion size in simultaneous lightness contrast as well as its possible interaction with grouping factors like similarity and proximity. The new results, together with earlier results, suggest that articulation effects are best understood within a theoretical framework that emphasizes grouping relationships between surfaces.

ON PRE-NEURAL INFLUENCES ON VISION: VISUAL PROCESSING BEFORE LIGHT ENTERS THE NEURAL PATHWAY

Katharina Rifai[1] and Markus Lappe[2]
[1]Institute for Ophthalmic Research, University of Tuebingen, Germany
[2]Institute of Psychology, University of Muenster, Germany

Visual perception is usually defined as the process of extracting information from the light-induced neural responses generated in the retina. Perceptual phenomena are primarily investigated with regard to the structure and capacity of the neural visual system. This symposium stresses the fact that the human visual system shapes visual input in a variety of ways even prior to detecting it on the retina: Optical properties of the eye strongly determine the retinal image appearance, eye movements shape spatio-temporal properties of the input luminance distribution, and retinal resolution/photoreceptor distribution determines the actual information content entering the visual system. Information available to be processed by subsequent visual processing is strongly shaped preneurally. Preneural visual processing can thus be determined an independent step in the visual hierarchy, often neglected in models and psychophysical concepts. An appraisal of preneural information might lead to a better understanding of visual information processing and provide important constraints for the explanation of neural perceptual peculiarities. The symposium is thus directed to a broad audience bringing into focus the preneural contributions to visual perception.

Modelling Early Influences on Visual Perception

Felix Wichmann and Heiko Schütt
Neural Information Processing Group, University of Tübingen, Germany

Models of spatial vision usually start with spatial frequency and orientation-specific channels applied to an image, which is already coded in contrast units relative to the background luminance ignoring earlier processing. To investigate the effects of preneural processing, we use an image-computable model of early spatial vision, which we published recently and investigate how this models' behaviour changes with different preprocessing schemes. We discuss the effect of local transformations to luminance contrast, which results in much higher sensitivity in dark image regions. Additionally, we discuss the optics of the eye, which are interestingly asymmetric in degrading more quickly towards the nasal visual field mimicking the faster decline in receptor density in this direction. We find big improvements of model performance for natural image masking data, when earlier influences are taken into consideration. These results argue for the importance of very early visual processing.

Visual Consequences of Fixational Instability Outside the Fovea

Michele Rucci[1], Martina Poletti[1], Norick R. Bowers[2], Jonathan D. Victor[3] and Janis Intoy[4]
[1]Department of Brain and Cognitive Sciences, University of Rochester, NY, USA
[2]Department of Optometry, University of California Berkeley, CA, USA
[3]Brain and Mind Research Institute, Weill Cornell Medical College, NY, USA
[4]Graduate Program in Neuroscience, Boston University, MA, USA

The human eye is always in motion during fixation. We have previously shown that this motion enhances sensitivity to high spatial frequencies, an effect likely mediated by neurons in the foveola. Outside the foveola, drift is commonly assumed to have little impact, as it covers a smaller fraction of cell receptive fields. Here, we show that eye drift improves sensitivity to high spatial frequencies even without foveal stimulation. We measured contrast sensitivity at 16 cpd with controlled retinal image motion in the presence of a central scotoma. Sensitivity is (a) impaired under retinal stabilization when drift motion on the retina is eliminated and (b) attenuated when retinal image motion is artificially reduced or enlarged. These results are well predicted by the spatial distribution of power conveyed by drift modulations on the retina. They indicate that eye drift exerts its action throughout the visual field.

Modulation of Stimulus Processing in Human Primary Visual Cortex Around the Time of Saccadic Eye Movements

Tamara Watson[1], Damien Mannion[2] and Colin Clifford[2]
[1]School of Social Sciences and Psychology, Western Sydney University, Australia
[2]School of Psychology, UNSW Sydney, Australia

Prior to a saccade, behavioural sensitivity is reduced for stimuli presented at fixation but increased for stimuli at the saccade target. To investigate this, we measured the blood-oxygen-level-dependent response of human primary visual cortex (V1) to stimuli presented immediately prior to or post a large saccade. Two stimuli were presented simultaneously: one close to the initial fixation location and the other close to the saccade target. The response to a stimulus presented prior to a saccade and close to the saccade target was significantly increased, consistent with

increased behavioural sensitivity. There was also an increased V1 response in the retinotopic location that the pre-saccadic stimulus would have occupied after the saccade had it remained onscreen. For stimuli presented immediately after a saccade, response was increased at the retinotopic location from which the eyes had just departed. The results highlight the complex dynamic neural processing occurring around saccades.

Visuomotor Representation of Space During Monocular Viewing in Primates

Frank Bremmer[1], Stefan Dowiasch[1] and Adam Morris[2]
[1]Department of Neurophysics and Center for Mind, Brain and Behavior – CMBB, Philipps-Universität Marburg, Germany
[2]Department of Physiology, Monash University, Australia

Filling-in describes a perceptual phenomenon in which vision during monocular viewing appears continuous, despite its discontinuity originating from the retinal blind spot (BS). Filling-in is considered to be an active process, whose neural basis is far from being understood. Here, we suggest that, at least for spatial vision, no such active mechanism must be assumed. Instead, the continuity of visual perceptual and motor space emerges as a feature of the readout of noisy population activity from visuomotor areas. We modelled monocular viewing with Gaussian noise in the position estimates upon readout of a sensory or motor map of space. Model data predicted a continuous spatial representation across the region of the BS. Human perception as well as human and monkey saccade data confirmed our predictions. We suggest that, more generally, filling-in could simply result from the readout of noisy populations of neurons in early visual areas. The study was funded by DFG: CRC-135 and FOR-1847; EU: PLATYPUS.

Domain Specificity of Oculomotor Learning After Preneural Changes in Sensory Processing

Miguel Eckstein and Yuliy Tsank
Department of Psychological and Brain Sciences, UC Santa Barbara, CA, USA

Humans visually process the world with varying spatial resolution and can execute eye movements optimally to maximize information acquisition for many everyday tasks. Diseases can introduce preneural changes in sensory processing such as a central scotoma. Here, we use a gaze-contingent scotoma and investigate whether humans can reprogram optimal saccades during a face identification task. We show that a scotoma changes the optimal fixation to identify faces from just below the eyes to the tip of the nose and the top of the forehead. However, even after 5,000 trials, humans do not change their initial fixations to adapt to the new optimal fixation points to faces, irrespective of the face size. In contrast, saccades do change for object-following and visual search tasks. Our findings argue against a central brain motor-compensatory mechanism that generalizes across tasks and suggest the possibility of separate domain-specific representations of learned oculomotor plans.

Monday, August 27—Oral presentations

Attention I

Visual Crowding in Densely Cluttered Displays Depends on the Identity and Distance of the Target's Nearest Neighbors

Erik van der Burg[1], John Cass[2], Kay Cordewener[1] and Chris Olivers[1]
[1]Department of Experimental and Applied Psychology, Vrije Universiteit Amsterdam, the Netherlands
[2]School of Psychology, Western Sydney University, Australia

Objects in peripheral vision are difficult to identify in the presence of nearby clutter. This visual crowding phenomenon has been investigated extensively using simple displays. Here, we investigated crowding in densely cluttered displays using genetic algorithms. Participants identified the orientation of a nearly vertical target line (6° eccentricity) among up to 284 distractor lines. In Experiment 1, each distractor was either horizontal or vertical. In Experiment 2, each distractor was vertical or absent (a gap). Displays supporting the highest accuracy were selected ("survival of the fittest") and combined to generate new displays. Performance improved over generations. Experiment 1 showed the emergence of horizontal distractors immediately flanking the target, with no evidence of interference beyond this radius. In Experiment 2, gaps evolved over a broader radius around the target. The results are consistent with crowding being determined by the identity and distance of the target's nearest neighbors.

Reacting to Critical Events During Multiple Object Tracking

Emily Crowe and Chris Kent
Department of Experimental Psychology, University of Bristol, UK

Classic multiple-object tracking tasks index accuracy by querying participants about the status, direction, or location of

objects at the end of a trial. This is atypical of the real world in which people react to critical events occurring while tracking. For example, a driver must brake if a child runs into the road. We recorded response time (RT) to an orientation change in one object. RT was faster for smaller set sizes and for static compared with moving objects, indicating a cost of tracking, over and above attention splitting. Real-world tracking also requires people to simultaneously monitor static and moving objects. For example, drivers attend to moving cars and static dashboard gauges. In displays consisting of both static and moving objects, RT was slower when a moving object changed orientation, indicating a tracking-induced lag in attention. These studies introduce a novel index of tracking capacity and present results to be accounted for by models of attention.

Feature-Specific Resources for the Colour and Orientation of Objects in Visual Short-Term Memory

Doug Barrett[1] and Michael Pilling[2]
[1]Department of Neuroscience, Psychology and Behaviour, University of Leicester, UK
[2]Department of Psychology, Health and Professional Development, Oxford Brookes University, UK

Resource models of VSTM predict an inverse relationship between recall and the number of objects in the scene, while slot models predict all-or-none recall of features for encoded objects. The current study contrasted these predictions using a change detection task for objects that varied in their colour or orientation. Experiment 1 manipulated feature-change and set size in the presence and absence of feature-specific cues. The data revealed comparable reciprocal relationships between set size and detection-accuracy for cued and uncued colour and orientation changes. Experiment 2 manipulated the number of values of each feature across cued and uncued objects in the display. Decreases in the accuracy of change detection were sensitive to the distribution of each feature on cued but not uncued trials. These findings are consistent with resource models of VSTM and demonstrate a dependency between the accuracy of recall for features and their distribution across objects in the display.

The Effect of Spatial Pre-Cues Is Not Only Pre-Attentive, It Is Largely Monocular

Joshua Solomon and Michael Morgan
Centre for Applied Vision Research, City, University of London, UK

Visual sensitivity can be heightened in the region of an appropriate pre-cue. Experiments with multiple, non-informative pre-cues suggest that this facilitation should not be attributed to focal attention. The number of simultaneously appearing pre-cues seems to be irrelevant. Contrast thresholds are lowest for targets that appear in a pre-cued position. Here, we report that pre-cues become 76% less effective when they and the target are delivered to different eyes. We must conclude that the mechanism responsible for heightened sensitivity has largely monocular input.

Attention and Self-Relevance: Enhanced Perception of Self-Relevant Visual Stimuli

Arash Sahraie, Aleksandar Visokomogilski, Marius Golubickis and C. Neil Macrae
Department of Psychology, University of Aberdeen, UK

Attention is referred to as a gating mechanism, controlling stimulus selection, depth of processing and access to conscious awareness. It is not a unitary mechanisms but multi-faceted, combining spatial and temporal aspects of stimuli and their integration across modalities. Self is a psychological construct that underpins one's interaction with the environment. It shapes our memory of objects and events and modulates their associated value and significance. A dynamic interaction between the neuronal circuitry underpinning attentional mechanisms and those for encoding self-relevance is postulated and termed Self-Attention Network (SAN). SAN enables prioritisation of processing and self-related objects and events. We demonstrate converging evidence for this account, from a series of experiments using different methodologies including binocular rivalry, continuous flash suppression and reaction times to cued stimuli when the cues are of varying levels of self-relevance.

Illusions of Morality: Visual Impressions of Causality Override Overt Judgment in Moral Decision-Making

Clara Colombatto and Brian Scholl
Department of Psychology, Yale University, CT, USA

We intuitively think of vision as among our earliest and most basic mental processes, and moral judgment as an especially sophisticated form of higher level thinking. How do they relate? Moral judgments are obviously influenced by what we see, but is this also true when our visual percepts conflict with our beliefs? Observers viewed a surveillance video of an accident involving two cars (A and B) and a pedestrian. A moved toward B (which was empty) until they were adjacent, at which point A stopped

and B started moving, eventually hitting a pedestrian. Observers judged A's driver to be less morally responsible for the pedestrian's injuries when the visual impression of A as having caused B's motion was eliminated—for example, by a playback "glitch" that momentarily paused the video just when A reached B. These and other results show how subtle (and morally irrelevant) features of visual processing influence moral judgment and how we can reveal this "psychophysics of morality."

Attention II

Spatial Spread of Visual Attention Measured Using Steady-State Visually Evoked Fields

Satoshi Shioiri[1], Takumi Miura[2], Kazumichi Matsumiya[2], Ichiro Kuriki[1] and Kaoru Amano[3]
[1]Research Institute of Electrical Communication, Tohoku University, Japan
[2]Graduate School of Information Sciences, Tohoku University, Japan
[3]Center for Information and Neural Networks, National Institute of Information and Communications Technology, Japan

We have been using steady-state visual evoked potential of electroencephalogram (EEG) to investigate neural mechanisms underlying spatial attention. While behavioral data suggest relatively narrow spread of spatial attention, spatial attention measured using SSVEP spreads broadly, extending into the area between the two attentional focuses in a divided attention task. To localize the brain site with such broad spatial attention tuning, here we measured magnetoencephalography (MEG), using the same stimulus conditions as in the EEG experiment. Analysis of MEG signals (steady-state visual evoked field, SSVEF) showed a broad spatial tuning of attentional modulation, as was found for SSVEP. To search brain areas responsible to the attentional modulation, we searched a dipole that could best explain the measured SSVEF. The dipole analysis showed the activity in the occipital lobe, suggesting that spatial attention tunes broadly in the early visual area.

Alpha Oscillations Do Not Reflect an Active Mechanism for Suppressing Visual Distractor Processing

Plamen Antonov, Ramakrishna Chakravarthi and Søren K. Andersen
School of Psychology, University of Aberdeen, UK

Alpha band (8–12 Hz) amplitude increases have been proposed to reflect an active mechanism for distractor suppression. To test this hypothesis, we concurrently recorded alpha band activity and steady-state visual evoked potentials (SSVEPs) elicited by attended and unattended stimuli. Participants covertly attended one of the two bilateral letter streams in order to detect infrequent target letters 'X' while ignoring the other stream. In line with previous findings, parieto-occipital alpha amplitude increased contralateral to unattended stimuli post-cue. Despite this, no suppression of SSVEPs elicited by unattended stimuli emerged, while those of attended stimuli were enhanced. These observations are incompatible with the suggestion that increases in alpha amplitude reflect a mechanism for distractor suppression in early visual processing.

Sequential Cued Shifts of Feature-Based Attention and the Effect of the Prior Attentional State

Søren K. Andersen and Leili Soo
School of Psychology, University of Aberdeen, UK

We examined the influence of the prior attentional state on the time course of cued shifts of feature-based attention. Participants observed two fields of continuously presented superimposed randomly moving dots of red and blue colour. Every 3 seconds, participants were instructed to shift attention to either red or blue dots or both in order to detect brief coherent motion targets of the cued dots while ignoring such movements of uncued dots (distractors). Attentional facilitation of early visual processing was assessed by means of steady-state visual evoked potentials elicited by the frequency-tagged flickering fields of dots. Both behavioral and EEG data consistently revealed that the effect of the previous attentional state wears out before the new attentional state is fully reached, that is, the time needed to shift attention is independent of the prior attentional state. This finding is inconsistent with the existence of a sequential 'disengage' step in attentional shifts.

How Top-Down Attention Alters Bottom-Up Preconscious Operations

Peter Tse[1], Peter Kohler[1], Eric Reavis[2], Liwei Sun[1], Kevin Hartstein[1] and Gideon Caplovitz[3]
[1]Department of Psychology, Dartmouth College, NH, USA
[2]Department of Psychiatry, UCLA Medical School, CA, USA
[3]Department of Psychology, University of Nevada, Reno, NV, USA

There is an ongoing debate about whether attention can alter subjective visual experiences. Here, we demonstrate that attention can modulate subjective visual experiences in areas as diverse as perceived color, brightness, size, shape, and direction of motion, as well perceived sound, in certain case where the stimulus is multiply interpretable. We hypothesize that attention can specify a domain or framework, such as a boundary or layer, within which constancy and other constructive processes subsequently operate. The outputs of these preconscious processes within the attended domain are then experienced consciously. Here, we demonstrate that human observers can deploy attention to selectively demarcate specific surface, layer, and figural boundaries and thereby affect which constructive processes will operate and how they will operate. Our data show that attention can reach down to a preconscious buffer up to 300 milliseconds postevent and define a domain within which constancies will be computed.

Gaze and Attention: Mechanisms Underlying the Therapeutic Effect of Smooth Pursuit Eye Movement Training in Spatial Neglect

Daniela Balslev and Alexandra Mitchell
School of Psychology and Neuroscience, University of St Andrews, UK

Left smooth pursuit eye movement training (LSPT) in response to optokinetic stimulation has become a promising rehabilitation method in spatial neglect. The mechanisms underlying the therapeutic effect, however, remain unknown. During LSPT, errors in visual localization in the direction of the eye movement indicate changes in the gaze direction estimate. Here, we show that in healthy participants LSPT causes not only a shift in the perceived direction of gaze but also a corresponding displacement in the allocation of attention. Both changes outlast the period of optokinetic stimulation. This result refines theoretical models for spatial attention by highlighting a tight coupling between attention and gaze. Furthermore, it forms a first step for establishing a causal link between the adaptation in the sensorimotor gaze signals and the recovery in spatial neglect.

Late Enhancement of Visual Attention After Multi-Method Brain Stimulation

Grace Carolyn Alys Edwards[1], Federica Contò[1], Loryn Bucci[2] and Lorella Battelli[1]
[1]CNCS Rovereto, Istituto Italiano di Tecnologia, Italy
[2]Boston College, MA, USA

Low-frequency repetitive transcranial magnetic stimulation (lf-rTMS) has been suggested as a tool for rebalancing interhemispheric inhibition in patients with right parietal lesions, resulting in improved bilateral attention. However, for clinical intervention, enduring effects are crucial. We paired transcranial random noise stimulation (tRNS) with lf-rTMS in healthy subjects to examine whether priming with tRNS can prolong subsequent lf-rTMS effects in the intraparietal sulcus (IPS) during a bilateral multiple-object tracking task. Results showed that tRNS extended the effect of lf-rTMS. Specifically, in the visual field contralateral to lf-rTMS, there was an initial decrement in tracking ability followed by a boost in performance lasting 90-minute post-stimulation. Late enhancement on contralateral attention may reflect functional compensation of inhibited IPS. Our results demonstrate a prolonged modulation of visual-field-specific attention after multi-method stimulation.

Memory and Learning

History Effects on Perception of Noisy Stimuli

Nikos Gekas and Pascal Mamassian
Département d'études cognitives, École normale supérieure, PSL Research University, CNRS, Paris

Human perception is partially affected by what has been previously experienced. These history effects presumably help tackle current sensory uncertainty by tracking past stimulus statistics. However, there is no definitive framework on how stimulus history affects perception at different levels of uncertainty. We asked observers to discriminate the orientation of ambiguous Gabor patches at high or low contrast, while we dynamically changed the orientation statistics of unambiguous high-contrast stimuli. We found both repulsive and attractive history effects at different timescales and differences between high- and low-contrast test patches. We present a computational model that can account for these different history effects by tracking both the volatility of past stimulus statistics and the observer's uncertainty on the current stimulus. This model may help resolve some conflicting results of history effects in the literature.

Serial Dependencies Occur at a Sensory Stage

Guido Marco Cicchini[1], Kyriaki Mikellidou[2] and David Burr[3]
[1]Istituto di Neuroscienze, Consiglio Nazionale delle Ricerche, Italy
[2]Dipartimento di Ricerca Traslazionale e delle Nuove Tecnologie in Medicina e Chirurgia, Università di Pisa, Italy
[3]Dipartimento di Neuroscienze, Università di Firenze, Italy

Serial dependencies refer to the hysteresis by which current judgments incorporate an average of the recent sensory history. Here, we investigate whether these effects are generated by sensory or by decision mechanisms. In Experiment 1, we displayed two stimuli and asked to reproduce their average orientation. We found that having trials with similar responses did not yield strong effects unless the stimuli were similar across trials. In Experiment 2, we run a standard orientation reproduction task and added uncertainty either in the stimulus or in the response; we found that uncertianty at the sensory stage modulates strongly serial effects; however, uncertainty at the response stage had blunt effects. Finally, we isolated trials in which previous response were near identical and found that previous stimuli still made a positive contribution. All this evidence indicates that sensory systems are a crucial locus for the generation of serial dependences and underscores their perceptual nature.

Posterior Cingulate Cortex and the Recognition of Highly Abstract Visual Stimuli

Boris B. Velichkovsky, Stanislav Kozlovskiy, Anton Rogachev, Alisa Suyuncheva and Alexandra Galanina
Department of Psychology, Moscow State University, Russia

The participants ($N = 17$, 11 females, mean age $= 19.5 \pm 2.0$ years) viewed single-colored highly abstract blots as stimuli (presentation time 400 milliseconds, eight different forms, and nine colors) and remembered them. After a 900-millisecond pause, they viewed a 2×2 matrix of four similar stimuli and had to recognize the previously shown blot. There were three sessions which differed by the feature that was remembered/recognized (1: form; 2: color, and 3: color and form). Visual event-related potentials were averaged for the matrix presentation, and sources of brain activity during recognition were computed using the dynamic statistical parameter mapping algorithm. Brain activity was similar for all the sessions, except for the high activation of the posterior cingulate cortex bilaterally (300 milliseconds from the matrix) which was only observed for the form recognition sessions (1 and 3). These data suggest a specific involvement of posterior cingulate cortex in the visual recognition memory for highly abstract stimuli. This research was supported by Russian Foundation for Basic Research, grant # 16–06-00065.

Unconscious Working Memory Outside the Focus of Attention

Marjan Persuh and Alexander Rue
Department of Social Sciences, BMCC, CUNY, NY, USA

According to state models, working memory consists of a limited capacity state, called the focus of attention, and the activated long-term memory. It is unclear whether objects outside the focus of attention are represented consciously or unconsciously. In two experiments, we asked participants to remember images of four objects or animals. A simple distraction task followed. In a free-recall task that immediately followed the distraction task, most participants were able to name three to four items. These results demonstrate that for some participants at least one item was not consciously represented. We then presented participants with color or contextual cues, associated with the remaining item. Across both experiments, about half of the participants were able to report the memorized item. These results demonstrate that the item was stored in working memory. Our results show that objects that move outside the focus of attention can be represented in working memory unconsciously.

Parallel Visual and Motor Selection From Working Memory

Freek van Ede, Sammi Chekroud, Mark Stokes and Kia Nobre
Oxford Centre for Human Brain Activity, University of Oxford, UK

Working memory enables our brains to hold onto visual representations that are anticipated to become relevant for guiding future behaviour. Despite this prospective nature, research has treated visual working memories in isolation from their prospective actions and has concentrated on the mechanisms of retention rather than utilisation. Using electroencephalogram, we show that working memory utilisation engages the simultaneous selection of both the visual representation and its associated action, calling on relevant visual and motor brain areas at the same time. Thus, once visual information has been encoded into working memory, the brain no longer needs to wait for the relevant representation to be selected before considering the appropriate action. Instead, both visual and motor attributes of working memories are readily accessible and, when an item becomes relevant,

selected in parallel. These data cast 'visual' working memory as a fundamentally prospective, action-oriented, function.

Four-Frame Humor Comic Manga Activates TPJ, MPFC, and Cerebellum in the Brain: An fMRI Study Based on Working Memory

Mariko Osaka[1], Ken Yaoi[2], Takehiro Minamoto[1], Miyuki Azuma[1], Mizuki Kaneda[1] and Naoyuki Osaka[2]
[1]Department of Psychology, CiNET Osaka University, Japan
[2]Department of Psychology, Kyoto University, Japan

Effect of humor comprehension on visual working memory performance was investigated using four-frame comic Manga using functional magnetic resonance imaging (fMRI) with funny and nonfunny Manga. The effect of humor was found for the fourth scene in which the punch line of the Manga was included. These findings suggest that visual humor comprehension, particularly of punch lines, promotes attention control system. In accordance with the time course of the four frames, fMRI activations changed serially. While reading the second frame (development scene), activation of the temporo-parietal junction (TPJ) was observed, followed by activations in the temporal and frontal areas during viewing of the third frame (turn scene). For the fourth frame (punch line), increased activations were confirmed in the medial prefrontal cortex (MPFC) and cerebellum. These findings suggest that humor comprehension evokes activation that initiates in the TPJ and expands to the MPFC and cerebellum at the convergence level.

Tuesday, August 28—Poster presentations

Three-Dimensional Vision, Depth, and Stereo

On the Possible Relativity of Spatial Frequency-Tuned Stereoscopic Processes Underlying Disparity Threshold Functions: A Study of Individual Differences

David H. Peterzell[1], Josee Ewane Enongue[2], Ignacio Serrano-Pedraza[3] and Jenny Read[2]
[1]College of Psychology, John F. Kennedy University, CA, USA
[2]Institute of Neuroscience, Newcastle University, UK
[3]Faculty of Psychology, Complutense University of Madrid, Spain

The stereoscopic disparity system represents depth structure via spatial frequency channels. So far, it has been assumed that these channels are tuned to retinal spatial frequency, in cycles per degree (CPD) of visual angle. However, we recently speculated that they may show size constancy, that is, be tuned to relative frequency, in "cycles per object" (CPO). To test this, we measured thresholds for disparity-defined horizontal sinusoidal corrugations embedded in dots for 27 observers. CPO and CPD varied independently by changing object size: 0.3 cpd stimuli appeared at 1, 2, and 3 cpo; 1.0 cpd at 1, 2, 3, 6, and 9 cpo; and 1.5 cpd at 1.5, 3, 6, 9, 12, and 15 cpo. We used an analysis of individual differences to identify factors. Principal component analysis of disparity sensitivities (log-arcsec), along with Varimax rotation, replicated two factors from our 2017 study. Factors/mechanisms are primarily tuned to CPD, with limited evidence for tuning to relative spatial frequency (CPO).

The Contribution of the Magnocellular and Parvocellular Pathways to Stereoacuity

Ignacio Serrano-Pedraza[1], Juan José Herrera-Morueco[1], Isabel Salmerón-Aguirre[1] and Marcos Bella-Fernández[2]
[1]Department of Experimental Psychology, Universidad Complutense de Madrid, Spain
[2]Faculty of Psychology, Universidad Autónoma de Madrid, Spain

Results from Kontsevich and Tyler suggest that stereopsis in humans is mediated strongly by the parvocellular (P) stream. However, recent results in Schizophrenia have linked an impairment in fine stereopsis with deficits in the magnocellular (M) stream. Here, 29 subjects performed six experiments to test the link between M and P pathways with fine stereopsis. In two experiments, we measured contrast thresholds using vertical gratings of 0.5 c/deg drifting at 10 Hz (M condition) and 10 c/deg drifting at 2 Hz (P condition). In four experiments, we measured stereoacuity using different tasks (two-alternative forced choice [AFC] vs. four-AFC) with static or dynamic random dots. Results show that M and P contrast thresholds were uncorrelated, and M thresholds did not correlate with any of the stereoacuity measurements. However, the stereoacuity obtained in all four tasks significantly correlate with P thresholds. Our results confirm that fine stereopsis is mainly mediated by the parvocellular stream.

How to Ensure the Expected Luminance and Contrast Without Nonocular Cues in Random-Dot Stereograms and Correlograms?

János Radó[1], Zoltán Sári[2], Gábor Jandó[1] and Péter Buzás[1]
[1]Institute of Physiology, Medical School, University of Pécs, Hungary
[2]Department of Technical Informatics, Faculty of Engineering and Information Technology, University of Pécs, Hungary

Random-dot stereograms and correlograms are designed to stimulate the binocular system selectively. Their usability requires that no monocular cues be present and average luminance and contrast be equal between the two eyes. In anaglyphic stereo, these requirements can only be met if unequal transmittances of and cross-talk between the filters are compensated for by careful choice of anaglyphic colors. Here, we show how the optimal set of colors can be calculated based on the luminance characteristics of the monitor phosphors and filter transmittances. We tested the lack of monocular cues psychophysically in a four-alternative forced choice test where participants ($n = 16$) had to tell the orientation of a Snellen-E target intended to be visible only binocularly. Correct responses were at chance level (>0.05) when anaglyphs were made with the calculated color values. Our method also allows determination of luminance and contrast values achievable within the gamut of a given video hardware.

Representing Relations Between Three-Dimensional Locations in Immersive Virtual Reality

Ellis Luise Gootjes-Dreesbach, Peter Scarfe and Andrew Glennerster
School of Psychology and Clinical Language Sciences, University of Reading, UK

In a recent demonstration of change blindness in three-dimensional scenes, performance on a change localisation task was strongly disrupted by the addition of changes to task-irrelevant connecting lines between objects (spheres). In immersive virtual reality, we investigated the effect of other task-irrelevant changes. We examined the effect of changing colour of the spheres on the detection of a movement in depth by one of the spheres. This did not produce the same disruptive effect as changing connecting lines, regardless of whether (a) colour changed but not grouping (b) colour pairings switched or (c) the size of the group. We also explored the effect of a task-irrelevant expansion of the whole scene on the same task (detection of movement in depth of one sphere relative to the others). Unlike colour changes, overall expansion affects the detection of relative object movement. This has implications for the way that colour, viewing distance and relative depth are encoded and accessed.

Identifying Neural Substrates Underlying the Qualitative Impression of Monocular Stereopsis: An EEG Study

Makoto Uji, Ines Jentzsch, James Redburn and Dhanraj Vishwanath
School of Psychology and Neuroscience, University of St Andrews, UK

Stereopsis, the qualitative impression of solid objects separated by a palpable space, is normally experienced in real scenes and three-dimensional (3D) movies and is conventionally explained on the basis of binocular disparity. However, stereopsis can also be experienced by viewing pictorial images monocularly through an aperture. We measured electroencephalogram (EEG) activity when viewing two-dimensional and 3D pictorial images during a control attentional task under conditions that did or did not generate stereopsis. We localized EEG oscillatory sources (beam former techniques) and conducted time–frequency analysis to examine power change in targeted frequency bands (alpha: 8–13 Hz and gamma: 55–80 Hz). Event-related gamma synchronization and alpha desynchronization were observed in the visual cortex. Interestingly, differential gamma synchronization was observed within the parietal cortex for the contrast isolating monocular stereopsis. Findings suggest that activity in the parietal cortex may underlie the qualitative impression of stereopsis.

Digital or Analogue? First Assessment of a Newly Developed Digital Stereotest in Adults and Children With and Without Amblyopia

Juliane Tittes[1], Alexander Baldwin[2], Peggy Feige[1], Licia Cirina[1], Yaroslava Wenner[1], Claudia Kuhli-Hattenbach[1], Hanns Ackermann[3], Robert Hess[2], Thomas Kohnen[1] and Maria Fronius[1]
[1]Department of Ophthalmology, Goethe University Hospital, Germany
[2]Vision Research Unit, McGill University, Canada
[3]Department of Biostatistics, Goethe University Hospital, Germany

Clinical stereotests (e.g., TNO) provide a small range and coarsely quantized disparity levels with no measure of variability. A new digital version, applying two staircase procedures and providing variability measure, was developed

at McGill and tested in Frankfurt. This version was presented on a three-dimensional monitor with shutter glasses at 76 cm viewing distance. Both tests use a random-dot-based circular stimulus. We assessed 34 normal-sighted and 27 amblyopic subjects with and without strabismus (4–59 years). Disparities for controls (range 11.2–160.6 arcsec) were correlated with age. In amblyopes (range 43.4–911.3 arcsec) correlation with visual acuity was poor. Repeated digital test results were highly correlated. Comparison with the TNO showed fair to moderate agreement. The new test has a larger range of quantifiable disparities and a measure of variability, making it more precise and creating new possibilities for research and clinic. This study was funded by ERA-NET NEURON.

Eye Height Affects the Perceived Layout of Interior Space

Christoph Freiherr von Castell, Heiko Hecht and Daniel Oberfeld
Department of Psychology, Johannes Gutenberg-Universität Mainz, Germany

In virtual environments, the physical eye height of the subject in the laboratory often does not correspond to the virtual eye height (i.e., the simulated eye position). Could this discrepancy confuse the observer or even invalidate findings based on virtual environments? We varied the observer's physical and virtual eye height (sitting vs. standing) independently of each other and stereoscopically presented interior spaces with varying spatial layout on a head-mounted display (HTC Vive). Subjects judged the width, depth, and height of the presented interior spaces. Our results show a strong effect of virtual eye height. Subjects perceived all spatial dimensions as larger when the simulation corresponded to a sitting compared to a standing viewing position. The variation of physical eye height did not have a substantial effect. In sum, our results indicate that observers mainly rely on visual information when it comes to judgments of the spatial layout of virtual environments.

Can Familiarity Be a Cue for Perceiving Depth?

Tadamasa Sawada[1], Elizaveta Mischenko[1], Ippei Negishi[2] and Elena Gorbunova[1]
[1]Department of Psychology, National Research University Higher School of Economics, Russia
[2]Media Informatics, Kanazawa Institute of Technology, Japan

Theoretically, it is possible to estimate the distance of a familiar object from an observer by comparing the size of the retinal image of the object to the memorized size of the object. Many studies have suggested that the human visual system can use some kind of "familiarity" information to perceive the distance of the object. These experiments, however, were not designed to minimize or to eliminate the effects of higher cognitive factors on the responses. In this study, we looked for a familiarity effect in two psychophysical experiments in which images of coins were the visual stimuli. The subjects' depth perception was measured with a multiple-choice task about the perceived depth order of the coins. The size of the familiarity effect was predicted to be substantial by a meta-analysis of the "familiarity" effects observed in prior studies, but the familiarity effect on depth perception was virtually zero in our experiment.

Short-Term Plasticity of 7T BOLD Ocular Dominance in Adult Human Primary Visual Cortex

Jan W. Kurzawski[1], Paola Binda[2], Claudia Lunghi[3], Laura Biagi[1], Michela Tosetti[1] and Maria Concetta Morrone[2]
[1]IMAGO Center, IRCCS Fondazione Stella Maris, Italy
[2]Department of Translational Research on New Technologies in Medicine and Surgery, University of Pisa, Italy
[3]Département d'études cognitives, PSL Research University, France

Primary visual cortex is generally resilient to plastic changes in adults, particularly ocular dominance that appears to be hardwired after the end of the critical period. However, we recently showed that 2 hours of monocular deprivation is sufficient to change blood oxygenation level-dependent (BOLD) response properties in V1 to narrow-band high-spatial frequency stimuli, measured with 7T functional magnetic resonance imaging. Here, we investigate the generality of the result using broadband stimuli with energy mainly at very low spatial frequency: binary noise matrices, composed of black/white checks of five sizes. Different sizes were presented in separate blocks and delivered separately to the two eyes. We find that 7T BOLD responses in V1 increased after deprivation for the deprived eye; they decreased for the non-deprived eye showing a significant TIME (before/after deprivation) $\times$ EYE (deprived/non-deprived) interaction. These results strengthen our recent evidence that primary visual cortex retains high potential for homeostatic plasticity in adults.

Investigating Biases in 3D Perception and the Effects of Signal Noise on Depth Discrimination

Jovan Kemp, Evan Cesanek and Fulvio Domini
Department of Cognitive, Linguistic, and Psychological Sciences, Brown University, RI, USA

We investigated whether (a) three-dimensional (3D) depth perception from individual cues is unbiased and (b) just-noticeable differences (JNDs) reflect the noise of depth estimates. Participants judged the depth of 3D paraboloids defined either by texture or by stereo information. First, participants judged variable paraboloid depths against three-standard two-dimensional (2D) line lengths in a staircase procedure. Next, individuals made the same judgments in a second task, but this time the variable comparison stimuli were 2D line lengths, and the standard stimuli were three fixed paraboloid depths determined for each participant by the points of subjective equality (PSEs) of the first task. All participants showed biased depth perception from individual cues. Participants who showed large JNDs in the first task were found to have reduced JNDs in the second task. This suggests that the JND is not a measure of the variability of depth estimates but instead reflects the ordinal discriminability of either 2D or 3D image signals, at odds with MLE models of depth perception.

Shape From Random Gradient and Contour Combinations

Maarten Wijntjes[1] and Robert Volcic[2]
[1]Perceptual Intelligence Lab, Delft University of Technology, the Netherlands
[2]Department of Psychology, New York University Abu Dhabi, UAE

Three-dimensional (3D) shape perception is mediated by shading and contour information. For depictions following the laws of optics, the light, material properties and 3D shape determine the shading pattern. Shading and contour are tightly linked; however, different mixtures of material and light can create many shading patterns which are compatible with the exact same contour. Here, we present a new stimulus generation method that ignores physical relations between shading and contour and instead merges independently generated 'shading' (Gaussian noise) and contours (level cuts of Gaussian surfaces). In two experiments, we asked observers if these dissociated shapes appear as solid 3D shapes. Experiment 1 suggests that contours are a contributing factor independently of the gradients. Experiment 2 suggests that specific gradient patterns (without dark 'valleys') evoke stronger 3D percepts. Together, these findings show that randomly combined gradients and contours can evoke the impression of 3D shape.

Adaptation

Changes in Eye Movement Strategies During a Discrimination Task in the Presence of an Artificial Central Scotoma

Paul Léné[1], Romain Fournet[2], Anne-Sophie Laurin[2], Frédéric Gosselin[1] and Aarlenne Khan[2]
[1]Département de Psychologie, Université de Montréal, Canada
[2]Département de Optométrie, Université de Montréal, Canada

We investigated whether the presence of an artificial central scotoma could induce the short-term changes in eye movements, thus modifying the foveal-target alignment. Thirteen healthy participants (six females, $M = 22.08$, standard deviation $= 1.88$) performed an orientation discrimination task over 10 days. Results showed a significant upward shift in the final position of the first saccade to the eccentric target over days (first $M = 0.48°$, last $= 0.77°$, $p = .05$) but no change in the final horizontal position of first saccade (first $= 0.91°$, last $= 0.76°$). There was also a significant decrease in correct discrimination time over days (first $M = 3{,}051$ milliseconds, last $M = 1{,}602$ milliseconds, $p = .0001$) and a slight increase in accuracy (first $= 87.7\%$, last $= 93.22\%$, *ns*). These findings suggest that the presence of an artificial central scotoma has an effect on saccade planning mechanisms resulting in improved discrimination performance. These findings demonstrate potential for rehabilitation for central vision impairment.

Visual Adaptation and Body Parts: Transfer of Adiposity Aftereffects Between Bodies and Hands

Klaudia Ambroziak, Elena Azañón, Marina Araujo and Matthew Longo
Department of Psychological Sciences, Birkbeck, University of London, UK

Several studies have shown that adaptation aftereffects for features such as identity and gender can transfer between bodies and faces. Furthermore, in previous research from our laboratory, similar cross-category transfer was observed for judgements about adiposity: Test bodies were judged as significantly fatter when they were preceded by a thin face as opposed to a fat face. In this study, we aimed to investigate whether adiposity aftereffects can also transfer between bodies and other body parts, that is, hands. On each trial, participants had to decide whether the body they saw was thinner or fatter than average. Participants performed the task before and after adaptation to a thin/fat hand. Consistent with previous studies,

after adaptation to a slim hand participants judged subsequently presented bodies to be fatter than after adaptation to a fat hand. These results suggest that body size adaptation can occur at a high level of visual representation.

Influence of Spectral Power Distribution and Photometry on Contrast Gain in Mesopic Illumination Conditions

Eduardo G. Vicente[1], Beatriz M. Matesanz[1], Isabel Arranz[1], Miguel Rodríguez[1], Santiago Mar[1], Juan A. Aparicio[1] and Pablo A. Barrionuevo[2]
[1]Departamento de Física Teórica, atómica y óptica, Universidad de Valladolid, Spain
[2]ILAV, CONICET – UNT, Argentina

The different levels of night lighting activate adaptation mechanisms such as contrast gain. The influence of different spectral power distributions on this mechanism is analyzed. Besides, two photometry systems are evaluated in terms of luminance effect on contrast gain. A two-channel Maxwellian optical system allowed assessing contrast gain of 13 young subjects at 10° of retinal eccentricity. High-pressure sodium and metal halide streetlamps provided a background luminance of 0.01 cd/m^2. A luminance meter provided a photopic measurement of luminance and an MES2 photometry system was used to mesopic luminance calculation. Contrast gain is significantly lower for sodium lamp using photopic photometry. However, mesopic photometry is responsible for an increase in background luminance for sodium lamp, improving contrast gain and leading to the absence of differences between lamps. Thus, spectral power distribution influence on contrast gain depends on the photometry system employed.

Visual Acuity Monitoring in Conditions of Psychosocial Isolation in a Mock-Up Spacecraft

Svetlana Dmitrieva[1], Olga Manko[1], Alexander Smoleevskiy[1], Nadezhda Vasilyeva[2] and Maria Gracheva[2]
[1]Department of Psychology, Neurophysiology and Psychophysiology of Activity, Institute of Medical and Biological Problems Russian Academy of Sciences, Russia
[2]Laboratory No 11 "Visual systems," Institute for Information Transmission Problems (Kharkevich Institute), Russian Academy of Sciences, Russia

Computerized monitoring of visual acuity has been conducted as a part of an international project SIRIUS during a 2-week isolation of six subjects ("team") in a mock-up spacecraft. The project provided an opportunity to study the influence of certain space flight factors: prolonged isolation, monotony of duties, reduced space of life, and LED illumination. Control group included six subjects matched to the team in age, sex, social status, education, and visual characteristics. Test stimuli were commonly employed tumbling E (TE) symbols and modified 3-bar (M3B) targets developed in the IITP RAS. In both groups, the visual acuity values obtained with the TE appeared to be higher than with the M3B by about 15% indicating systematic overestimation due to harnessing of information contained in the low-frequency parts of the TE Fourier spectra. Statistically significant effect ($<.001$) of the team isolation—decrease of visual acuity by 10%—was only detected when the M3B stimuli were employed.

Topographic Numerosity Maps Dynamically Adjust to the Presented Numerosity Range

Yuxuan Cai[1], Jelle van Dijk[2], Wietske Zuiderbaan[2], Wietske van der Zwaag[2], Ben Harvey[2] and Serge Dumoulin[2]
[1]Department of Experimental and Applied Psychology, Spinoza Centre for Neuroimaging/VU University Amsterdam, the Netherlands
[2]Department of Experimental Psychology, Helmholtz Institute, Spinoza Centre for Neuroimaging/Utrecht University, the Netherlands

Numerosity, the set size of a group of items, is essential to guide behavior and decisions. Previously, we have described a network of topographic maps in human association cortex representing small numerosities in an orderly fashion. Here, we investigated the neural representation of larger numerosities. Using 7T functional magnetic resonance imaging, we measured responses elicited by viewing different numerosities. The small numerosity range stimuli consisted of 1 to 7 dots alternated with baseline periods of 20 dots. Larger range stimuli numerosities ranged from 1 to 64 dots with a baseline of 512 dots. We found the same topographic numerosity maps as in our previous studies. Here, we show the same cortical regions responding to both small and large-range numerosities. Furthermore, the preferred numerosity scaled with the stimulus range. These results indicated that neuronal populations organized in topographic numerosity maps dynamically adjust their preferred numerosity to the numerosity range that is presented.

Face Adaptation Aftereffects on Local Information

Ronja Mueller[1], Sandra Utz[2], Claus-Christian Carbon[2] and Tilo Strobach[1]
[1]Department of Psychology, Medicalschool Hamburg, Germany
[2]Department of Psychology, University of Bamberg, Germany

Previously, inspected faces can affect the perception of faces seen subsequently. The underlying mechanisms of these face adaptation aftereffects have been considered to be based on sensory adaptation. More recent studies, however, also suggest a high-level effect and an adaptation on a representational memory basis. Although research on adaptation effects in faces seems to be well-advanced, it still lacks a systematic analysis of its generalizability to different types of face information since most research indeed focused on configural information. Adaptation effects on local feature information, however, are barely investigated. We investigate these effects employing color alteration as implementation of local feature changes. Results of our studies indicate that face adaptation aftereffects to local features differ from effects regarding configural information, most probably due to perceptual interpretation of such properties as being more transient than those of configural aspects.

Co-Circularity Opponency in Texture Perception

Hiromi Sato[1], Frederick Kingdom[2] and Isamu Motoyoshi[3]
[1]Department of Informatics, Kogakuin University
[2]McGill Vision Research, Department of Ophthalmology, McGill University
[3]Department of Life Sciences, The University of Tokyo

In natural images, oriented edges tend to have co-circular structures ranging from straight lines and shallow curves to Ls and Vs. These information are essential not only for detection of object contours but also for the appearance of texture. We here introduce a novel aftereffect and texture mixture to demonstrate opponent interactions between obtuse and acute type of co-circular structures. An adaptation experiment showed that after prolonged observation of a texture composed of obtuse element pairs (e.g., curves), the subsequent random texture appeared to be dominated by acute element pairs (e.g., Vs) and vice versa. A mixture experiment demonstrated a cancellation in texture appearance by the opposite co-circular structures; textures with acute element pairs appeared to be a random texture when obtuse structures are added. These results suggest that co-circularity is a principal bipolar axis that determines the appearance of texture images.

Color Appearance During Color Adaptation After Changing the Lighting Color

Shino Okuda[1] and Katsunori Okajima[2]
[1]Faculty of Human Life and Science, Doshisha Women's College of Liberal Arts, Japan
[2]Faculty of Environment and Information Sciences, Yokohama National University, Japan

We conducted an experiment using a 1/6 scale model room equipped with LED lamps. Nine kinds of lighting conditions, varying in correlated color temperature (CCT) and duv, were prepared by controlling six kinds of LED chips. Three participants observed the center of a front white wall and evaluated the color appearance with a color scaling method in 10 to 30 seconds at 10-second intervals and in 1 to 5 minutes at 1-minute intervals after changing the lighting. They answered the ratio of achromatic and chromatic components of the color stimulus, and the ratio of the selected two colors from four primary colors in each condition 3 times. The results indicate that temporal variations of chromatic response during color adaptation can be formulated by exponential functions with different coefficients and that the coefficients depend on the differences of duv and correlated color temperature CCT between the lighting conditions before and after changing. This study was supported by JSPS KAKENHI Grant Number 25282006 and 17H01947.

Aging

Collinear Facilitation: Effects of Older Age and Temporal Asynchrony

Yu Man Chan, Cassandra J. Brooks and Allison M. McKendrick
Department of Optometry and Vision Sciences, The University of Melbourne, Australia

Collinear facilitation is a spatial vision phenomenon where the detectability of a central grating is enhanced by high-contrast flankers. Neurophysiology points to collinear facilitation being derived from lateral facilitation between V1 neurons in addition to extrastriate feedback. Human behavioural work suggests that the two processes can be separated by varying the flanker onset timings (FOT). We measured Gabor contrast detection thresholds on 19 younger and 17 older adults at six FOT to infer effects of aging on the two processes. Thresholds were normalised to the no-flanker condition to assess facilitation or masking. Thresholds were unaltered by forward masking flankers but were elevated by backward masks. Facilitation occurred at synchrony and was significantly reduced in older adults. Our data show altered local spatial

interactions in older adults only when the flankers are presented at close temporal proximity, while feedback interactions are relatively unaffected by age.

What Drives Age Effects on the Speed Accuracy Trade-Off During Reaching?

Jutta Billino[1], Elena Hitzel[1] and Constanze Hesse[2]
[1]Department of Experimental Psychology, Justus-Liebig-Universität Gießen, Germany
[2]School of Psychology, University of Aberdeen, UK

It has been consistently shown that speed-accuracy trade-offs (SAT) shift toward slower speed and higher accuracy across the adult life span. However, it is still controversial whether this shift is based on slowing due to neural deficiencies or rather a strategic choice because older adults prefer to avoid mistakes and thus sacrifice speed voluntarily. We investigated the malleability of the SAT in a manual pointing task ($N = 44$, age range: 21–69 years). In a baseline condition, movements were instructed with only moderate speed and accuracy demands. In contrast, in a stress condition, strong emphasis was put on speed. Results indicated an accelerated trading of accuracy for speed in the stress condition. Interestingly, age predicted SATs under moderate speed–accuracy requirements but not when speed demands were emphasized. We conclude that age-related differences in SATs can be attenuated by explicit instructions and are not exclusively determined by declining processing resources.

What Contributes to Age Effects on Tactile Suppression During Reaching?

Lena Klever, Dimitris Voudouris, Katja Fiehler and Jutta Billino
Department of Experimental Psychology, Justus-Liebig-Universität Gießen, Germany

It has been recently suggested that ageing increases reliance on sensorimotor predictions, resulting in reduced sensory sensitivity during self-generated compared to externally induced actions. However, contributions of sensory and cognitive mechanisms to this effect are still ambiguous. We investigated age differences in tactile sensitivity during reaching and at rest. In young and older adults, tactile sensitivity was reduced during reaching compared to rest, indicating consistent attenuation of tactile information. Importantly, the suppression was significantly more pronounced in older adults. Regression analyses revealed that individual differences in sensory precision as well as in cognitive control capacities are strong predictors of the increase in detection thresholds during reaching. Our findings corroborate an enhanced impact of sensorimotor predictions in old age. This age effect seems to be driven not only by increased sensory noise but also by declined cognitive resources.

Cognitive and Anticipated Properties of the Moving Object With Age

Masaru Takeichi[1], Takeyuki Arai[2] and Kinya Fujita[3]
[1]Politics and Economics Undergraduate School, Kokushikan University, Japan
[2]Faculty of Human Science, Takachiho University, Japan
[3]Department of Computer and Information Sciences, Tokyo University of Agriculture and Technology, Japan

The purpose of this study was to investigate anticipated and cognitive property with age. We reported a decline of cognitive function from the data of four groups (10–80 seconds) in European Conference on Visual Perception 2017 and the scope of each group was 20 years. In this study, it was 10 years, and the data were divided into seven groups for detailed analysis. Forty-two (19–81 years) persons participated in this experiment. They were required to answer the position of a moving object at the moment of a visual trigger stimulus, which is presented after the occlusion of the object with five levels of delay (200–1,000 milliseconds) by changing the color of the occluding board. The object moved from left to right at a visual speed of 10 deg/s on display. Anticipated velocity in occluded task and cognitive velocity in visible task were calculated from the answered position and the trigger delay. Cognitive velocity decreased and anticipated one increased with age. The difference between cognitive and anticipated velocity showed a characteristic tendency.

Applied Vision

Analysis of Indices of Lie: Congruency Between Nonverbal and Verbal Behavior

Jessica Vascotto[1], Tiziano Agostini[1] and Jasna Legiša[2]
[1]Department of Life Sciences, University of Trieste, Italy
[2]NeuroComScience, Italy

The present study aimed to verify through analysis of nonverbal and verbal behavior if it is possible to delineate new reliable lie's indices. Eighty participants (40 males and 40 females) took part in this study. The task was to lie or tell the truth about a movie's scene that they had seen previously. The interviews were videotaped and audio-recorded. The Facial Action Coding System, Emotional Facial Actin Coding System, Interpretation System of Facial Expressions, and Body Coding System were used

to verify the presence of smiles, doubt expressions, incongruities, facial illustrators, gesture illustrators, gestures of openness, and manipulations. The results highlighted a high number of incongruities between verbal and nonverbal behavior in a lie situation.

Does Hangover Affect Visual Attention and Working Memory?

Serena Mingolo[1], Mauro Murgia[1], Valter Prpic[2], Tiziano Agostini[1] and Eleonora Bilotta[3]
[1]Department of Life Sciences, University of Trieste, Italy
[2]Division of Psychology, De Montfort University, UK
[3]Physics Department, University of Calabria, Italy

It is well known that acute alcohol intoxication affects visual perception, attention, and other cognitive processes. However, it is not clear whether similar effects still occur when blood alcohol level (BAL) approaches zero, after an acute intoxication. To better understand this phenomenon, we tested a sample of 40 participants in hangover versus sober conditions. We used the Stroop task and the operation span task (operations + word recognition). The results revealed no differences in the Stroop task; however, a higher number of errors was found in the hangover condition for the operation task but not for the word recognition. Interestingly, while in the sober condition, the accuracy for the operation and word recognition tasks correlates ($r = .69$; $p < .001$), in the hangover condition, no correlation was found. It suggests that participants in hangover could not perform well in both tasks at the same time. This may have important implications when complex tasks are required (e.g., driving).

Different Sound Pitch Effects on Motor Performance of Individuals in Head-Mounted Virtual Reality

Anil Ufuk Batmaz, Michel de Mathelin and Birgitta Dresp-Langley
ICube - UMR 7357, CNRS, France

In addition to visual feedback, auditory feedback is sometimes used to enhance the motor performance of subjects in immersive virtual reality. To test the effect of sound, Oculus DK2 with a leap motion hand-tracking system was used. Eighteen subjects had to retrace horizontal and vertical cylinders and a torus in the virtual scene with the index finger of their dominant and non-dominant hands in all possible movement directions. Eight fundamental C sounds from an 88-key piano were played whenever a task error occurred. Results showed that subjects were faster and more precise with middle frequency sounds; other sounds affected motor performance negatively. Subjects were faster and more precise with vertical shapes, and for top to bottom finger movements with their dominant hand. It is concluded that there is an optimal pitch which improves task performance. Handedness, hand movement direction and object orientation are other variables that need to be considered for performance assessment.

Investigating Effects of Color Temperature on Conflict Handling Behavior

Steffen Ronft and Tandra Ghose
Department of Psychology, University of Kaiserslautern, Germany

Ambient light conditions not only affect visual acuity but also mood, emotion, memory, and cognitive performance. Now, people are exploring different color temperatures for offices and personal spaces. Conflicts occur in everyday situations, for example, dealing with irresponsible colleagues close to deadline or uncooperative landlords. Mood influences conflict handling behavior; hence, we explored if subtle changes in color temperature also affects it. We tested 68 participants for two conflict situations in two light conditions: warm—2500 K versus cold—3800 K at illuminance level 450 lx. We used the Thomas Kilmann Instrument for evaluating characteristics of negotiation style, which can be competing, collaborating, compromising, avoiding, or accommodating. We used self-evaluation for estimating changes in motivation, creativity, comfort, happiness, and calmness. Significant effects: Creativity was higher in warm light ($p = .00$), and conflict handling style was less avoiding in warm light ($p = .03$).

Detecting Uncertainty While Assembling a Camping Tent

Brian Sullivan[1], Hazel Doughty[2], Walterio Mayol-Cuevas[2], Dima Damen[2], Casimir Ludwig[1] and Iain Gilchrist[1]
[1]School of Experimental Psychology, University of Bristol, UK
[2]Department of Computer Science, University of Bristol, UK

We are developing a wearable computing system to predict user uncertainty and provide task guidance, similar to an interactive video how-to-guide. We present data from participants assembling a camping tent. Participants answered a survey about their experience with tents, then wore a head mounted first-person camera and an eye tracker while assembling a tent outdoors, using instructions as needed. After completion, participants

viewed their first-person video and rated their frame-by-frame uncertainty with a specialised video viewer. Videos were annotated to delineate assembly steps. Using the survey, assembly annotation and eye-tracking records, we analyse the data for cues to predict frame-by-frame uncertainty ratings. We present several analyses of participant behaviour and preliminary results for predicting frame-by-frame uncertainty using eye-tracking features (e.g., fixation durations, saccade rate) by modelling the data set with support vector machines and neural networks.

Perceptual and Cognitive Load in Graph Reading

Isabella Fuchs-Leitner, Lisa Falschlunger and Heimo Losbichler
Campus Steyr, University of Applied Sciences Upper Austria, Austria

According to Lavie's load theory of selective attention and cognitive control, perceptual load and cognitive load have different effects on visual processing: While high perceptual load can interrupt distractor processing and consequently lead to better performance compared to conditions of low perceptual load, the reversed pattern is found for the different levels of cognitive load. In the current study, we tested these predictions in an applied setting of graph reading. We varied the levels of both, cognitive and perceptual load on the same trials. Additionally, in half of the trials, an irrelevant colour singleton distractor was present. Although response times, accuracy measures as well as various eye movement measures did reflect differences in load, we did not find any confirmation of the predictions of load theory on distractor processing. These findings are in line with previous studies in applied settings, and implications for future studies are discussed.

A Dynamic Approach of Searching Behaviour in Webpages

Alexandre Milisavljevic[1], Thomas Le Bras[1], Matei Mancas[2], Coralie Petermann[3], Bernard Gosselin[2] and Karine Doré-Mazars[1]
[1]VAC, Paris Descartes University, France
[2]Numediart Institute, University of Mons, Belgium
[3]R&D, Sublime Skinz, France

The visit of a webpage is driven by multiple bottom-up and top-down factors, such as the inner characteristics of the webpage, the goal or the user profile. In the present experiment, we studied the goal's effects on participants' visual behaviour while browsing 18 fully scrollable webpages. To achieve this, we asked them to carry out two kind of tasks: Free Viewing task and Target Finding task. Preliminary results showed the influence of the task on the scanpath length, the horizontal spatial dispersion of the fixations and the amplitude of the saccades. However, scanpath's characteristics evolve during the navigation which highlight explore/exploit modes. Further analyses suggest that the dynamic of the scanpath is also influenced by the target detection.

Does Body Dissatisfaction Influence Our Ability to Accurately Identify Distorted Body Images?

Nicole Thomas, Alessia Mattia, Elizabeth Matthews and Ellie Aniulis
College of Healthcare Sciences, James Cook University, Australia

We are surrounded by social media, which contributes to our perception of the "ideal" body. Body image is influenced by perception; repeatedly viewing unrealistically thin bodies can shift our perception of average body size. We distorted images of female bodies, in increments of 5%, to determine whether participants are able to identify the extent to which images have been digitally altered. We also measured participants body shape dissatisfaction, ideal body shape, time spent on social media, and their BMI. We anticipate participants will underestimate the extent to which images have been distorted, indicating a tendency to perceive overly thin female bodies as average in size. We also expect that participants' feelings about their own bodies, and their perceived ideal body will influence their ability to correctly identify percentage of distortion. Our findings will clarify whether frequent exposure to thin body ideals and personal body dissatisfaction influence our perception.

The Effect of Screen Orientation on Depth Perception and a Comparison Between Virtual Reality Systems

Cyril Vienne[1], Vincent Honnet[2], Stéphane Masfrand[2], Christophe Bourdin[1] and Jean-Louis Vercher[1]
[1]ISM, Aix-Marseille Université, France
[2]MSRV, Groupe PSA, France

This study describes the effect of screen orientation when looking at virtual three-dimensional (3D) scenes. We took advantage of three Virtual Reality (VR) systems: two with front, ground and side screens (CAVE-like systems) and one with a single one (an HMD), to investigate the effect of screen orientation on perceived depth. This latter was varied relative to observers visual axes by asking them to judge depth for objects displayed at different elevations.

The angle between the visual axes and the screen surface normal was 0°, 35° or −35°. We tested the following conditions: near object versus far object, 3D object alone versus object displayed in a structured visual scene, and a VR system with back projection versus a VR system with direct projection to control for the effect of specular reflection. The results revealed that screen orientation affected perceived depth in CAVE-like VR systems. Screen distance was also revealed as a major predictor, revealing the importance of screen distance in such displays.

CAPTCHA Using Combined Stereo Vision and Amodal Completion

Toshiaki Yamanouchi and Kazuhisa Yanaka
Information Media, Kanagawa Institute of Technology, Japan

Completely Automated Public Turing test to tell Computers and Humans Apart (CAPTCHA) is commonly used to prevent bots from exploiting web services. Subsequently, the technique shifted toward a method requiring a high degree of judgment ability, such as selecting, from a group of images, one which is similar to a sample that shows a specific animal type. By contrast, approaches that utilize human visual capabilities are also available; examples of these are amodal completion and stereo vision. This is a new trend created in the fear that bots can overcome CAPTCHA by using artificial intelligence technology which has recently remarkably progressed. However, if you use fast computers or discover efficient algorithms, then the effect will be limited. For this reason, further increasing analysis cost by combining amodal completion and movies is necessary. We propose CAPTCHA with high analysis cost by combining amodal completion and stereo vision.

Experimental Approach to Motorcyclist Detection by a Car Driver

Vincent Boucher[1], Fabrice Fournela[1], Romain Dronneau[1], Nicolas Basily[2] and Mylène Besnier[2]
[1]DLAn, CEREMA, France
[2]DSMT, ESEO, France

Representing 3% of French road traffic, motorcyclists account for nearly 20% of total mortality. To reduce this hecatomb, the CEREMA tries to understand how a motorcycle is detected in the lateral perception field of a car driver during an overtaking. To do this, we installed a photometric camera and an acoustic antenna in a vehicle. The originality of our study lies in the analysis of visual contrasts perceived in the lateral field and in their association with auditory acuity. Results lead to two different areas in which first vision is predominant and then hearing becomes more important. This defines a "sensorial alert field" depending on motorcycle position.

Art

What Happens When You Perceive a Sun Eclipse?

Claus-Christian Carbon
Department of General Psychology and Methodology, University of Bamberg, Germany

Total sun eclipses (TSE) are amongst the rarest moments in life, accordingly there is a lack of systematic research on such perceptual phenomena. We conducted an empirical study in the United States on the occasion of TSE taking place 21 August, 2017. We asked for (a) expectations: Which perceptions (visual, acoustic, temperature, etc.) did they expect beforehands to have while witnessing the solar eclipse? (b) perception: Which perceptions did they actually had? (c) aha-insights: Have there been any kind of aha-insight moments while witnessing the solar eclipse? and (d) liked best: What did they liked best about experiencing the solar eclipse? On the basis of all fully completed reports ($N = 40$), we generated a categorization system for each of the questions revealing that participants often perceived strong emotional, social, and even spiritual experiences: strong signs for experiencing the sublime. Results make clear how strongly perception of TSE can impact social, cognitive, and emotional dimensions.

Exploring Artwork In Situ: Empirical Aesthetics Making Use of Mobile Eye Tracking

Doga Gulhan and Johannes Zanker
Department of Psychology, Royal Holloway, University of London, UK

Empirical aesthetics in laboratory settings controls experimental conditions and measurements but limits 'ecological validity' by restricting experience and using only reproductions of artworks. Mobile eye tracking is crucial to advance experimental work, allowing us to investigate aesthetic experience with original artwork in 'natural' setting. We investigated eye movements of 13 participants exploring an art installation—Salon Diagonale by L. Goetz—covering walls of an otherwise empty room in Compton Verney Art

Gallery with a grid of diagonal colour patches that mark vertical three-dimensional corners and illusory two-dimensional boundaries. Gaze data visualised as heat maps revealed strong trends, such as fixation preference on both real and illusory edges between colour patterns. These preferences were analysed quantitatively for boundaries and individual colour patches. Our future work will be expanded to eye tracking using a virtual reality headset in a digital reconstructing of the same installation.

Historic Faces: An Investigation of Head and Eye Direction in Art Portraits Across 1,000 Years of Western History

Tobias Matthias Schneider, Claus-Christian Carbon and Alexander Pastukhov
Department of General Psychology and Methodology, University of Bamberg, Germany

Lateralization effects in art (self)-portraits as well as in selfies is scientifically well-documented. There are some incidental notions that the preference for a certain facial side seem to change across art epochs-systematic research, however, is missing. However, 1,183 portraits spanning a period of ~1,000 years of Western art history were randomly presented on a split screen. Participants had to match a virtual three-dimensional head with the outward appearance (head plus eye direction) of the art portrait via mouse and keyboard. Analyses of head posture + gaze direction revealed that until the era of Renaissance, gaze was mostly directed frontally in relation to the head orientation, with the result of a quite static, relatively static look. From the Renaissance on, an attention-catching and more dynamic, vivid and enigmatic look was developed and successfully executed by sophisticated painting including mild degrees of exotropia. These means paved the way for expressive depictions, for example, today's selfies.

Individual Differences in Aesthetic Evaluations of Visual Arts (2): Does Aesthetic Dimension of Value Relate to the Aesthetic Evaluations of Bad Arts?

Tatsuya Miyashita[1], Kiyoe Cho[2], Atsushi Kimura[3] and Takashi Oka[4]
[1]Graduate School of Literature and Social Sciences, Nihon University, Japan
[2]Graduate School of Human-Environment Studies, Kyushu University, Japan
[3]College of Risk Management, Nihon University, Japan
[4]College of Humanities and Sciences, Nihon University, Japan

Several studies have reported the factors which determine individual differences in aesthetic evaluations of visual arts. Our previous studies suggested that the aesthetic dimension of value (ADV) was a crucial factor relating to the individual differences in aesthetic evaluations. However, the paintings used in our previous studies were selected from the masterpieces painted by famous artists. The present study explored whether the ADV would relate to aesthetic evaluations of poor works. Undergraduates ($N = 166$) were asked to rate seven paintings selected from the Museum of Bad Art on four scales of aesthetic evaluation and to complete a questionnaire assessing their degree of the ADV. A regression analysis revealed that the ADV significantly related to aesthetic evaluations of poor works ($R^2 = .29$, $\beta = .54$, $p < .01$). The results suggest that the ADV related to the subjective value of the paintings regardless of their reputation.

Subverting the Naïve (mis)Perception of Animal Intelligence: From the Scala Naturae to the Darwinian Tree Via a Simple Survey

Cinzia Chiandetti[1], Andrea Dissegna[1], Ryuta Nakajima[2] and Graziano Fiorito[3]
[1]Department of Life Sciences, University of Trieste, Italy
[2]Department of Art and Design, University of Minnesota Duluth, MN, USA
[3]Department of Biology and Evolution of Marine Organisms, Stazione Zoologica Anton Dohrn, Italy

While the scientific community is accumulating evidence of remarkable mental abilities in non-human animals, people have many naïve beliefs on their cognitive functions. To increase public awareness of animals' abilities and defeat ill-informed perceptions, we devised a survey in which participants first rated the perceived intelligence of a range of animals; next, they watched a clip of animals' abilities as documented by scientific investigations; finally, they rated again the intelligence of the same species. The results showed unequivocally that, in the beginning, people placed organisms on an intuitive ladder with structurally simpler animals on its lower part and more complex animals on its upper part by associating structural simplicity to lower mental capabilities. After watching the clip, people subverted the scores exchanging the ladder with a Darwinian-tree-like representation: Within a few minutes of intervention, we modified people's conception of animals' intelligence.

Effects of Context on Aesthetic Appraisal of Curviness

Jelena Blanuša[1] and Slobodan Markovic[2]
[1]Laboratory for Experimental Psychology, Faculty of Philosophy, Belgrade, College of Vocational Studies in Subotica, Serbia
[2]Laboratory for Experimental Psychology, Faculty of Philosophy, University of Belgrade, Serbia

This study aimed to examine how sense of threat in different contexts (interiors) influence curviness appraisal. The experiment was presented as an interior design study: Participants were asked to rate on 7-point scale how much would they like to see particular picture in different context. Based on the pilot study, we defined three types of contexts: unthreatening (children's room), neutral (kitchen) and threatening (workshop). Seventy-two black and white, curved and angular geometric figures (matched by complexity and symmetry) were used as stimuli. The results showed that preference for curviness was determined by context. Curved figures were significantly higher rated in unthreatening context; in neutral context, curviness and angularity were equally rated; and angularity was preferred over curviness in threatening context. Study suggested that preference of curviness can be modulated by context and, additionally, that sense of threat and aesthetic appraisal are interconnected.

Is the Unattractiveness of Human Body an Inversion of Its Attractiveness?

Slobodan Markovic, Tara Bulut and Ljiljana Lazarevic
Department of Psychology, University of Belgrade, Serbia

Attractiveness of human body is evidently normally distributed: Body parts with average sizes are the most attractive; their reduction or enlargement decreases the attractiveness. In the present study, we investigated whether the distribution of unattractive body parts sizes is inverted normal (U-shaped). Forty-two participants of both genders were asked to create the most attractive and the most unattractive male and female figures using a program for computer animation. Participants performed this task by adjusting the size of six body parts: shoulders, chests/breasts, waist, hips, buttocks, and legs. The results are generally in line with our predictions: Normal distributions for all attractive body parts and U-shaped distributions for the most unattractive female body parts were obtained. However, distributions for the most unattractive male body parts were skewed. The difference in distributions of male and female unattractiveness requires further investigation.

Consistency in Preference for Fractal-Scaling Properties Across Synthetic Noise Images and Artworks

Catherine Viengkham and Branka Spehar
Department of Psychology, UNSW Sydney, Australia

Natural scenes and artworks are characterised by unique fractal-scaling properties, which can be quantified using measures like fractal dimension. When parametrically manipulated in synthetic images, fractal dimension is remarkably predictive of within-individual aesthetic preferences even when these images are visually distinct (e.g., greyscale, two-tone, edges). Our study directly compares within-subject preferences for varying fractal-scaling properties in both synthetic images and real-world art. We found average preference peaked for intermediate D values in both image classes, but consistent patterns of individual differences for high and low D also emerged. Preference patterns across image classes were largely consistent within-individuals and, while slightly fluid, were resistant to extreme changes. These findings support the role of fractal-scaling properties as a key determinant of aesthetic value and as a strong predictor of individual differences in aesthetic preference.

Attention

The Reference Frame for Inhibition of Return Is the Full Hemifield

Tatiana Malevich[1], Elena Rybina[2], Elizaveta Ivtushok[2], Liubov Ardasheva[2] and Joseph MacInnes[2]
[1]Physiology of Active Vision Laboratory, Werner Reichardt Centre for Integrative Neuroscience, Germany
[2]School of Psychology, National Research University Higher School of Economics, Russia

As a foraging facilitator, inhibition of return (IOR) must be coded in spatiotopic coordinates. Early reports confirmed this suggestion, but these results have been recently challenged. The present study was designed to examine the reference frame of IOR and to test whether retinotopic IOR might be a part of the spatiotopic IOR gradient. We conducted four experiments with spatiotopically and retinotopically cued coordinates and an intervening saccade between the cue and target presentations. We alternated the response modality (manual and saccadic) and the cue-target spatial distance (fixed and continuous). Our data showed evidence for no independent source of retinotopic IOR, neither at discrete locations nor as a gradient; moreover, we observed the spread of IOR across the whole validly cued hemifield. We propose that these results indicate a strategy to attend and then inhibit the entire cued hemifield.

Mechanisms Underlying the (Re) Alignment of Covert and Overt Visual Attention

Inga Korolczuk, George Houghton and Charles Leek
School of Psychology, Bangor University, UK

It is widely assumed that attention comprises overt and covert orienting mechanisms. Following a peripheral cue covert and overt attention can be decoupled. But how are they subsequently realigned? We examined whether realignment towards a fixated (central) location is determined solely by the time since cue onset or whether it is also influenced by the spatial location of a subsequent reorienting cue. We used the spatial cueing paradigm to examine this in the context of inhibition of return (IOR) – that is, slower target detection at previously cued locations. After an exogenous cue, a reorienting cue was shown at either central fixation or peripherally. IOR was greater following the central than the peripheral re-orienting cue. This indicates that the direction of realignment modulates the inhibition of previously cued locations. We propose that stronger inhibition arising from central reorienting cues reflects a fundamental bias to realign covert and overt attention at a central fixation.

Perceptual Set Within the "Attentional Blink"

Ivan Makarov and Elena Gorbunova
Department of Psychology, National Research University Higher School of Economics, Russia

The experiment involved dual-target rapid serial visual presentation task in which 15 stimuli were displayed within each trial. The time of presentation for one stimulus was 90 milliseconds; interstimulus interval was 10 milliseconds. Shape and size of stimuli were varied. Targets could have two, one, or no shared features. There were three colors: green for distractors, yellow for first target stimulus, and blue for second target stimulus. The second target was presented on five different lags after first target. Participants task was to detect both targets on each trial. Repeated measures analysis of variance revealed the significant impact of the lag factor and the number of shared features factor. Attentional blink was observed only for no shared features condition. The perceptual set created by the first target reduces the interference in working memory and prevents the second target omission for the conditions with one and two shared features.

Evidence for the Existence of Three Regimes of Number Perception

Antonella Pomè[1], Giovanni Anobile[2], Aurora Scabia[1], Guido Marco Cicchini[3] and David Burr[1]
[1]Department of Neuroscience, Psychology, Pharmacology and Child Health, University of Florence, Italy
[2]Department of Developmental Neuroscience, Stella Maris Scientific Institute, Italy
[3]Institute of Neuroscience, National Research Council, Italy

Humans possess the capacity to estimate and represent numerosity over a large range of stimulus quantities. Traditionally, two distinct mechanisms for numerosity perception have been proposed: subitizing, for numbers up to four and estimation for larger numerosities. We have recently proposed that for very densely packed arrays a third mechanism comes into play. In this work, we provide further evidence for the existence of a third regime for numerosity using reaction times and cross-modal attentional studies. We found that reaction times are lowest in the subitizing range, high and constant for sparse items, descending again to low values at higher densities (Experiment 1). We then confirm that both visual and auditory attention affect subitizing much more than estimation and go on to show that the attentional costs rise again for very dense patterns (Experiment 2). Taken together, these results reinforce the idea of three regimes in the processing of numerosity.

Quantifying the Contribution of Covert and Overt Spatial Attention to Perceptual Decision-Making

Samantha Parker[1], Andrew Heathcote[2] and Matthew Finkbeiner[1]
[1]Department of Cognitive Science, Macquarie University, Australia
[2]Division of Psychology, University of Tasmania, Australia

Spatial attention is oriented across the visual field in two ways: covertly (without eye movements) and overtly (with eye movements). While much is known about the benefits of focussed attention on visual perception, little is known about the individual contributions of covert and overt attention on perceptual decision-making. In this study, participants completed an orientation discrimination task, while a visual cue directed attention covertly and blocked task instructions directed eye movements. Our results revealed both covert and overt orienting of attention to individually influence performance. Within the same task, the preparation of an eye movement towards the target improved performance as did a valid arrow or peripheral cue. Computational modelling was then used to quantify each mechanisms contribution. The results suggest that both covert and overt orienting mechanisms contribute

to perception and that covert attention may not always be yoked to a saccade.

Awe Broadens Attention

Muge Erol and Arien Mack
Department of Psychology, New School for Social Research, NY, USA

Awe is an emotional response that follows perceived vastness (visual or conceptual) and accommodation to it. Empirical investigations have shown that the experience of awe predicts change in self-related appraisals, attitudes, and behaviors but is there any change evident at the perceptual level? In two separate experiments, the effect of awe on the breadth of attention was investigated using a 16-trial global/local similarity judgment task. Mood was induced by showing observers (Os) a 360° virtual reality video prior to the task. In both experiments, observers in whom awe was induced were more likely to pick global figures than Os in a no induction/baseline condition ($p = .001$, Experiment 1, $N = 30$) and Os in a neutral mood condition ($p = .000$, Experiment 2, $N = 30$). Self-reported awe ratings correlated with the tendency to pick global figures ($r = .44$, $p = .001$). These findings suggest that awe affects perception by increasing the breadth of attention.

Investigating Neurophysiological Correlates of Joint Action

Hossein Abbasi, Dominik Dötsch and Anna Schubö
Cognitive Neuroscience of Perception and Action, Philipps-University Marburg, Germany

Joint actions are situations in which an agent and a partner each take over one part of a task. Still unknown is how agents deploy their attention in such tasks. We examined to what extent an agent represent the partner's task in a jointly performed visual selection task. Participants were shown search displays which contained a combination of two colored stimuli (one presented laterally and one on the vertical midline) and background distractors. We examined whether the electroencephalogram of the agent showed differential activity when her or the partner's target color was shown. Our results showed target negativity and negative lateralized alpha in response to the agent's target. Crucially, we also found negative lateralized alpha for the partner's target presentations. These results show that agents deploy attention to the partner's target as well, indicating that they also represent her task. Performing a task with a partner seems to shape human visual perception irrespective of task relevance.

Letter Spacing Modulates Lateralization of EEG Alpha Oscillations During Natural Reading

Béla Weiss, Ádám Nárai and Zoltán Vidnyánszky
Brain Imaging Centre, Research Centre for Natural Sciences, Hungarian Academy of Sciences, Hungary

Lateralization of alpha oscillations is closely related to visuospatial attention deployment and inhibition of distractor stimuli; therefore, its examination is crucial to understand the neural processes underlying natural reading. We investigated the effects of letter spacing on lateralization of baseline and evoked alpha power by analyzing fixation-related brain activity in a saccadic reading experiment using eye-tracking and electroencephalogram recordings. We found rightward lateralization of occipito-temporal baseline alpha power that was significantly weaker in the increased spacing condition. Furthermore, we obtained significantly stronger lateralization of evoked alpha synchronization and desynchronization in normal spacing condition compared to altered ones from 100 to 180 milliseconds and from 220 to 290 milliseconds after fixation onset, respectively. These findings may indicate that experienced readers perform better at visuospatial attention deployment when reading text with familiar orthographic properties.

Effect of Attention on the Perceptual Grouping

Chiahuei Tseng, Chien-Chung Chen and Satoshi Shioiri
Research Institute of Electrical Communication, Tohoku University, Japan

Object-based attention is a good example of how attention interacts with environment properties, but it is hard to isolate involved mechanisms as attentional benefits are usually reflected by reduced response time and increased accuracy, consequences from multiple stages of processing. We propose a solution by combining the cueing paradigm and noise-masking paradigm to better characterize the processes. Four U-shape contours, equal distance from the fixation, are used to produce different degrees of grouping by Gestalt laws of closure, similarity, and proximity by manipulating their relative orientation and distance. Participants' detection thresholds against various noise levels are measured, while the cue and targets have opportunities to be confined under two different grouping principles (e.g., closure vs. similarity). We model the grouping strength with the target threshold change when grouping occurs (or fails to occur) to provide a quantitative model for attentional facilitation.

We Cannot Ignore a Smile!—EEG Correlates of the Interaction Between Ambiguity and Attention

Lukas Hecker[1], Ellen Joos[1], Anne Giersch[2], Ludger Tebartz van Elst[3] and Jürgen Kornmeier[1]
[1]Perception and Cognition, Institute for Frontier Areas of Psychology and Mental Health Freiburg, Germany
[2]INSERM U1114, Cognitive Neuropsychology and Pathophysiology of Schizophrenia, University of Strasbourg, France
[3]Department of Psychiatry and Psychotherapy, Medical Center, University of Freiburg, Germany

We recently found smaller amplitudes of two event-related potential (ERP) components when participants observed ambiguous stimuli compared to disambiguated stimulus variants ("ERP Ambiguity Effect'). We investigated the role of attention for this effect using stimuli with ambiguity at low (Necker cubes) and high complexity levels (emotional face expression). In different experimental conditions, attention was either focused on the stimuli or on the fixation target. We found the ERP Ambiguity Effect for both stimulus types when they were attended. When attention was shifted to the fixation target, this effect was much weaker for the face stimuli and completely absent for the cube stimuli. Interpretation: The ERP Ambiguity Effect reflects high-level reliability estimation of perceptual outcomes. If the cube stimuli are not attended, their perceptual evaluation may be suppressed. A high intrinsic saliency of faces/emotions weakens these suppressive forces, resulting in a reduced ERP Ambiguity Effect.

Subjective Time Expansion With Increased Stimulation of Intrinsically Photosensitive Retinal Ganglion Cells

Pei-Ling Yang[1], Sei-Ichi Tsujimura[2], Akiko Matsumoto[2], Wakayo Yamashita[2] and Su-Ling Yeh[3]
[1]Department of Psychology, University of Illinois Urbana-Champaign, IL, USA
[2]Department of Science and Engineering, Kagoshima University, Japan
[3]Department of Psychology, National Taiwan University, Taiwan

Intrinsically photosensitive retinal ganglion cells (ipRGCs) contain photoreceptors that are especially sensitive to blue light. Nevertheless, how blue light and ipRGCs affect perceived duration remains unsolved. We used oddball paradigm and manipulated the background light to examine how blue light and ipRGCs affect perceived duration. In the oddball paradigm, participants were asked to judge the duration of the target (oddball) compared to that of the standard, with a two alternative-forced-choice procedure. In Experiment 1, we independently manipulated the background to be either blue or red. In Experiment 2, a set of multi-primary projector system that could manipulate the ipRGC stimulation were used to clarify the contribution of ipRGCs. Results showed that both blue light and increased stimulation of ipRGCs could expand perceived duration. These results shed lights on further investigations of how ipRGCs affect the timing mechanism and future applications in lighting designs.

Do the Eye-Movement System and the Arm-Movement System Contribute Independently to Attentional Orienting: A TMS Study

Soazig Casteau, Jacob Hathaway, Amanda Ellison and Daniel T. Smith
Department of Psychology, Durham University, UK

Saccadic eye and arm movements are preceded by a shift of attention. Prior studies reported that attentional resources are allocated independently for eye and hand movements, implying separate attentional mechanisms. Frontal Eye Fields (FEF) have a central role in the deployment of visuo-spatial attention, namely, the coupling between eye movements and visual attention. The question remains whether FEF is also involved in the coupling between arm movements and attention. Using MRI-guided Transcranial Magnetic Stimulation (TMS), we stimulated FEF in order to test for separate pre-motor attentional mechanisms for eye and arm movement and further describe the role of the FEF in attentional orienting. TMS over FEF increased saccade latency and delayed the onset of pointing movements. Moreover, it perturbed pre-saccadic perception; however, performance was less affected by TMS in the pointing task. This suggests that attentional resources for eye and arm movements are allocated independently.

Disassociation Between Reaction Time and Pupil Dilation in the Stroop Task

Ronen Hershman and Avishai Henik
Department of Psychology, Ben-Gurion University of the Negev, Israel

The Stroop task gives rise to two conflicts: information (color vs. word meaning) and task (name the color vs. read the word) conflicts. However, behavioral indications for task conflict (response to congruent condition longer than to neutral condition) appear under very restricted conditions. We conducted a Stroop experiment and measured reaction time and pupil dilation. The results show a clear dissociation between reaction time and pupil dilation.

We found the regular reaction time pattern congruency and interference effects. In contrast, pupil dilation showed information conflict—larger pupil dilation to incongruent than to congruent and neutral conditions—and task conflict—larger pupil dilation to congruent than to neutral conditions. Moreover, pupil indications for task conflict appeared earlier than indications for the information conflict. These results suggest that pupil changes could indicate conflict even in the absence of behavioral indications for the conflict.

Attentive Tracking of Moving Objects Whose Depth in 3D Gradually Change

Anis Ur Rehman[1], Yuji Nosaki[2], Ken Kihara[3] and Sakuichi Ohtsuka[2]
[1]Department of Liberal Arts and Sciences, National Institute of Technology, Kagoshima College, Japan
[2]Department of Information Science and Biomedical Engineering, Graduate School of Science and Engineering, Kagoshima University, Japan
[3]Department of Information Technology and Human Factors, National Institute of Advanced Industrial Science and Technology, Japan

Attentive tracking study reported that participants' performance deteriorated when to be tracked targets whose depth of 50 cm abruptly changed from one plane to another in real three-dimensional (3D) space. Likewise, humans have limited ability to reset their attention when all targets are distributed on a single plane prior to the attentive tracking task. However, in the natural world, human track moving objects whose depth in 3D change gradually. Therefore, in this study, we examined attentive tracking of moving objects whose depth in 3D gradually changed in stereoscopic viewing. Our results demonstrate that participants could track targets whose depth changed gradually in 10 cm even when all targets were presented on a single plane from the beginning of each trial. The findings additionally revealed that participants were able to reset their attention during the task when depth was kept shorter. Further research is necessary to investigate this effect on longer depth condition.

The Simon Effect Is Modulated by Effector-Stimulus Proximity and Not by Hand-Stimulus Proximity

Gioacchino Garofalo[1], Leonardo Longo[2] and Lucia Riggio[2]
[1]Department of Humanities, Social Sciences and Cultural Industries, University of Parma, Italy
[2]Department of Medicine and Surgery, University of Parma, Italy

Recent evidence has shown that hand-stimulus proximity modulates visual processing in many tasks. It seems that even the Simon effect (SE) is enhanced when the hands are close to the stimuli. This effect has been related to the spatial coding properties of the bimodal visuotactile neurons. We performed two experiments to test the bimodal neurons account by dissociating the position of the response from the position of the hands. In Experiment 1, the location of the response coincides with the location of the hands. A greater SE was found when the hands were near the stimuli. In Experiment 2, the response location was dissociated from the hands location since the response was performed by the feet, whereas hands were placed near or far from the stimuli. No SE difference was found between near and far hands location. Taken together, our results show that the proximity of the hands increases the SE only when hands are response effector. This is not easily explained by the bimodal neurons account.

Conflict in the Pupil: Luminance and Cognitive-Based Modulation

Suzon Ajasse and Jean Lorenceau
Equipe Vision et Calcul Naturel, Institut de la Vision, France

During natural scene exploration, salient regions often overtly attract the gaze. Meanwhile, the pupil, mainly driven by foveal stimulations, changes the eyes optic. We tested whether salient preferential looking zones induce pupil constriction and are "chosen" to enhance visual processing. We first measure pupil size with four constantly visible, spatially distributed disks of different luminance that subjects must fixate in succession, and confirm that pupil size depends on the saliency of the gazed stimulus. Using similar settings, we then measure spatial frequency discrimination while subject fixates each disk. Although we do find that pupil size still varies with the luminance of the gazed stimulus, discrimination performance is independent of pupil size whose dynamics are more variable, presumably due to increased additional load. We conclude that looking at salient regions governs pupil dynamics but is not a general strategy used to improve the eyes optic and visual processing.

Attention Distractibility Trait Associations With Self-Reported Attention Deficit and With Variation in *KTN1* Gene

Iiris Tuvi[1], Jaanus Harro[2], Evelyn Kiive[3] and Talis Bachmann[1]
[1]Faculty of Law, University of Tartu, Estonia
[2]Department of Psychology, University of Tartu, Estonia
[3]Department of Special Education, University of Tartu, Estonia

We conducted a simple visual search experiment with irrelevant distractor to examine its suitability for assessing attention distractibility in general population and explore its association with variation in the protein kinectin encoding gene (KTN1, rs945270, and rs8017172). The opposite ends of this trait should describe people with high and low ability to maintain focused attention. In the large population-representative sample ($n = 451$), symptoms of attention deficit and hyperactivity had been measured at age 15, 18, and 25 years. Irrelevant distractor prolonged reaction time (distractor interference) and significant positive correlation were found with self-reported hyperactivity at age 18 years but not at age 25 years. Distractor interference was significantly smaller in KTN1 rs945270 C/C genotype as compared to G-allele carriers. Attention distractibility trait may be associated with the volume of putamen and with self-reported attention deficit during school years but not in young adulthood.

Metacognition of Precision and Latency During Spatial Orienting of Attention

Samuel Recht[1], Vincent de Gardelle[2] and Pascal Mamassian[1]
[1]Cognitive Studies, Ecole Normale Supérieure, France
[2]Centre d'économie de la Sorbonne, Paris School of Economics, France

How well can we estimate the validity of our own perception when that perception fluctuates because of attention? To address this issue, we adapted a "Wundt clocks" paradigm to probe both exogenous and endogenous visuospatial attention. Participants looked at six clocks at a fixed eccentricity that rotated at a fixed speed but different phases. At a random time, one of the clocks was either cued peripherally (exogenous) or centrally (endogenous), and when the clocks stopped, participants were requested to report the hand position at cue onset. After two trials, participants chose the one they felt more confident to be correct. Compared with a baseline condition, participants reported a delayed clock hand in the exogenous condition and more so in the endogenous condition. Nevertheless, participants were more precise in high-confidence trials, indicating that they could successfully monitor their perceptual uncertainty during both exogenous and endogenous orienting of spatial attention.

Bilateral Field Presentation Modulates Subitizing

Chiara Tagliabue and Veronica Mazza
CIMeC, Università degli Studi di Trento, Italy

Studies on the bilateral advantage effect argue that independent attentional resources are allocated to each hemifield for the individuation of relevant items. We tested whether subitizing, a phenomenon strongly linked to selective individuation, is influenced by the bilateral field presentation of targets. Additionally, we investigated whether the need for target-distracter selection results in a magnification of the bilateral advantage effect. Participants enumerated a varying number of targets (from two to six) presented unilaterally or bilaterally, with or without distractors. The results indicated a significant bilateral advantage only for the condition with distractors and only for small quantities (2–3), with an opposite trend for larger numerosities (5–6). Thus, in enumeration tasks, the bilateral field presentation improves multiple target processing only when small numerosities are presented and only when an additional distinction between targets and distracters is required.

Context-Specific Habituation of Attentional Capture

Francesca Bonetti and Massimo Turatto
Center for Mind/Brain Sciences—Department of Psychology and Cognitive Sciences, University of Trento, Italy

Attentional capture triggered by an onset distractor is subject to habituation, an ancestral form of plasticity consisting in a response reduction to a repeated irrelevant stimulation. Habituation is usually considered a form of non-associative learning, but associative models have also been developed according to which the habituated response can be context-specific. Although several studies on animal models support the associative nature of habituation, direct evidence in the human beings is scant. Starting from our previous study, here we further investigated whether habituation of attentional capture is context-specific. We documented that habituation of attentional capture triggered by a peripheral onset distractor is strictly related to the visual context in which it occurs, and that a context change caused the recovery of capture for the same visual distractor, a result that cannot be explained by the non-associative models of habituation.

When Modality Matters: Inhibition of Return in and After a Visual Search

Margit Höfler[1], Katrin Liebergesell[2], Iain Gilchrist[3] and Christof Körner[2]
[1]Department for Clinical Neurosciences and Preventive Medicine, Danube University Krems, Austria
[2]Department of Psychology, University of Graz, Austria
[3]School of Experimental Psychology, University of Bristol, UK

Inhibition of return (IOR) facilitates visual search, as it discourages the immediate reinspection of items. We have previously demonstrated saccadic IOR (longer saccadic latencies to inspected vs. non-inspected items) within two consecutive searches but not across them, suggesting that IOR is not maintained after a search. However, other researchers have demonstrated IOR even after a search when measured via manual response. Here, we tested whether IOR within and after search depends on the response type (manual vs. saccadic). Participants searched in letter displays while their eye movements were recorded. Within and immediately after each search, we probed an item which had or had not been recently fixated. Participants either saccaded to the probe or pressed a button once it appeared. We found saccadic IOR within but not after the search; a trend for manual IOR was observed in both cases. Our findings suggest that IOR during and after a search depends on response modality.

A Functional Magnetic Resonance Imaging Study of Bodily Efference Signal in Searching Self-Controlled Moving Object

Qiaobo Qu, Kazuma Horita and Takako Yoshida
School of Engineering, Tokyo Institute of Technology, Japan

The current understanding is that the integration of predicted state and sensory feedback is implicated in the sense of agency. However, it remains to be elucidated whether attention is involved in this process. We aimed to determine their relationship based on the basic visual search experimental paradigm. Here, we compared brain activity detected by functional magnetic resonance imaging under two visual-stimulus conditions elicited by active and passive hand movements. The functional magnetic resonance imaging results indicated that Left Cerebellum 9 tended to activate when attention was focused on the visual object controlled by the active hand motion. By setting Left Cerebellum 9 as the seed for the psychophysiological interaction analysis, the ventral frontal cortex and inferior parietal lobule, which is involved in attention, were found. These results suggest that attention plays a role in the facilitation of the sensory feedback that matches the ongoing action.

Selective Impact of tRNS on Resting State Functional Connectivity After Visual-Attention Training

Federica Contò, Grace Carolyn Alys Edwards and Lorella Battelli
CNCS Rovereto, Istituto Italiano di Tecnologia, Italy

Transcranial random noise stimulation has been shown to boost visual attention performances. Yet, the understanding of cortical dynamics after stimulation is still unknown. This study investigates the potential impact of neuromodulation on large-scale cortical networks by analyzing the effect of multisession transcranial random noise stimulation (tRNS) coupled with training on resting-state functional connectivity. Thirty-three subjects were divided into one of the three conditions depending on the brain stimulation site (parietal, hMT+, and sham) and received 25 minutes tRNS for 4 consecutive days while training on a visual attention task. Resting-state data were collected on the first and last day. Results show that resting state functional connectivity patterns increased within the main nodes of the Dorsal Attention Network after parietal stimulation. Importantly, visual performance improved for subjects of this group only. This work highlights the importance of a network perspective to understand the impact of tRNS on brain and behavior.

To the Edge of Gaze and Beyond: Visual Attention Is Not Limited by the Oculomotor Range

Nina M. Hanning[1], Martin Szinte[2] and Heiner Deubel[1]
[1]Allgemeine und Experimentelle Psychologie, Ludwig-Maximilians-Universität München, Germany
[2]Department of Cognitive Psychology, Vrije Universiteit Amsterdam, the Netherlands

In line with the influential premotor theory of attention, some recent studies claimed that exogenous attention is constrained by the range of locations reachable by eye movements. To test this assumption, we measured attention at locations inside and outside the oculomotor range (OR). Using the eye abduction paradigm, participants saccaded to an exogenous attention cue, which in some cases appeared outside the OR, leading to saccadic undershoot. We took orientation sensitivity at the cue and at various control locations as a proxy of spatial attention. We found the typical attentional benefit at the cue independent of whether it occurred inside or outside the OR. Even when

the saccade aimed at a cue outside the OR, but landed too short, we observed an unaltered deployment of attention to the cue, yet no attentional advantage at the actual saccade end point. This shows that visual attention is not limited by the OR, ruling out saccadic motor plans as a prerequisite of covert attention.

Persistent Attentional Salience of Reward Cues Despite Reward Devaluation and Incentive Learning

Matteo De Tommaso and Massimo Turatto
CIMeC, University of Trento, Italy

Reward cues can irrationally grab attention even when the paired reward is devalued. We tested whether the cue attentional salience, once established, can be abolished. Participants learned cue-reward (beverage) associations while thirsty (Experiment 1). Then, reward was devalued by quenching participants' thirst. A visual search task showed that the reward cues maintained their salience despite reward devaluation. Next, in a new incentive-learning phase, the cues were paired with devalued reward, and another visual search task was run to test for cues salience changes. To test whether the cues salience extinguishes with time, the second visual search was performed 15 minutes (Experiment 2) or 1 week (Experiment 3) later. Results showed that (a) the best reward cue attracted attention even after reward devaluation and (b) the reward cue salience was not changed by a new incentive-learning phase with a devalued reward and was not extinguished after 1 week. Implication for addiction is discussed.

Working Memory Capacity as a Predictor of Contralateral Delay Activity and Strategy Use in Multiple Object Tracking: An ERP Analysis

Gurmukh Panesar and Anne Richards
Psychological Sciences, Birkbeck College, University of London, UK

Visual memory and tracking capacity have been found to be sensitive to neural differences in controlling access to working memory and efficiency in tracking targets. Here, participants were separated using their operation-span task score and then completed a separate tracking task, where the last second of each trial was masked and objects under the mask were either stationary or moving. It was predicted that neural differences would emerge that would equate to similar behavioural scores across groups. Main effects of load and trial nature were found in accuracy rates and an interaction in contralateral delay activity between group, load and nature, indicating that only high-capacity individuals tracked at full capacity in high load, moving trials. This suggests that different neural strategies can be used to gain similar accuracy scores and that compensatory mechanisms may be implemented by low-capacity individuals in order to efficiently track and predict coordinates of targets.

Feature-Based Attention Modulates fMRI BOLD Response in Areas MT and V4

Robert Hess[1], Benjamin Thompson[2], Alexander Baldwin[1] and Simon Clavagnier[1]
[1]Department of Ophthalmology, McGill University, Canada
[2]Department of Optometry, University of Waterloo, Canada

Previously, Braddick et al. used separate stimuli for motion and form to show that extra-striate responses did not correspond with dorsal and ventral regions. We have since developed a single global stimulus with combined motion and orientation coherence. This was used in a functional magnetic resonance imaging (fMRI) paradigm to study whether attention to motion or form selectively modulate V1, V4, or MT. Subjects were cued to respond to either orientation direction or motion direction of the stimulus. 3T fMRI data were analyzed using mrVista. An analysis of variance on BOLD response amplitudes found an interaction between region of interest (ROI) and cue: $F(2,6) = 10.6$, $p = .01$. Area V4 response was increased in conditions where subjects attended to the orientation of the stimuli. The response in area MT was increased where subjects attended to motion. The response in area V1 was not differentially affected by cue. Our results show specific modulation of dorsal and ventral stream extra-striate areas by cued attention to motion and form.

Thin and Plus-Size Models Differentially Modulate Attentional Asymmetries

Ellie Aniulis and Nicole Thomas
College of Healthcare Sciences, James Cook University, Australia

Advertisements depicting idealised thin bodies are common online, with plus-size models appearing less often. Prior research shows different attentional patterns when viewing thin versus larger bodies. We aimed to determine how viewing different body types impacts performance on the landmark task, a measure of pseudoneglect. Participants completed a baseline landmark task to determine their initial attentional biases. A second task wherein a pair of images (thin models, plus-size models

and neutral images), one in the left visual field, one in the right, were presented prior to the landmark task was then completed. For pairs consisting of a thin and plus-size model, attentional asymmetries were more leftward when the thin model was presented on the left. When the plus-size model was presented on the left, typical leftward biases were reduced such that they were no longer significant. We suggest that attention was drawn both toward the thin model and away from the plus-size model.

Spatial Attention With Rescorla's "Truly Random Control"

Alexey Asvarisch and Joseph MacInnes
School of Psychology, National Research University Higher School of Economics, Russia

The allocation of attention can occur not only in space but also in time. Application of Rescorl's "truly random control" procedure about independency of cues and targets allowed us to differentiate the impact of endogenous (voluntary) and exogenous (automatic) components of temporal attention on the performance separately and within their interaction. In a random-dot motion task, variation of luminance and motion of dots that represent the cue affects the engagement of exogenous mode. Temporal contingency between cues and targets or its absence affects the impact of endogenous mode. Combining these conditions, the results are as follows. For endogenous cues, we see improvement of both speed and accuracy at early cue target onset asynchrony. For exogenous cues, we see improvement of response times but not accuracy. When both are involved, we observe a trade-off of speed and accuracy. This parallels from the auditory modalities of alertness cueing but with purely visual stimuli.

The Visual Saliency of Emotional Objects

Michał Kuniecki, Kinga Woloszyn, Krzysztof Waniak and Joanna Pilarczyk
Institute of Psychology, Jagiellonian University, Poland

Objects tend to be more visually salient that the background of natural scenes as shown by Elazary and Itti. Emotional images and key objects within them tend to be attended faster and for longer than neutral ones. Here, test whether the driving force behind this phenomenon of the attentional dominance of emotional objects can be explained by valence-related systematic differences in visual saliency. Six hundred images from well-established databases of emotional stimuli (like IAPS, EmoPics, NAPS, GAPED) were evaluated for the location of the key object by 241 participants. Saliency model was derived from graph-based visual saliency algorithm. We show that emotional objects are not more visually salient than neutral ones to contrary objects in negative images are in fact less salient than objects in neutral images. Therefore, attentional preference for emotional content is driven rather by semantics than by visual saliency.

Modulation of Top-Down Attention in the Human Face-Processing Network: An MEG Study

Daniel Baldauf and Eelke de Vries
Center for Mind/Brain Sciences, University of Trento, Italy

We recorded magnetoencephalography using compound face stimuli that allowed for independently entraining rhythmic changes in various parts of a face (eyes and mouth) as well as changes in facial identity. Our analyses revealed that various subnodes of the human face-processing network were entrained differentially according to their functional specialization: The occipital face area was most responsive to the frequency, at which face parts (e.g., the mouth) changed, the fusiform face area was selectively entrained by the rhythmic updating of facial identity, and the superior temporal sulcus was mostly entrained by rhythmic changes in the eyes region. Top-down attention to the mouth, eyes, or identity of the face selectively modulated the neural processing in the respective area. We provide new insights in the hierarchical organization of the face-processing network and the attentional modulation among its components.

Attentional Rhythms Across Space

Peijun Yuan, Yi Jiang and Ying Wang
Institute of Psychology, Chinese Academy of Sciences, China

Emerging evidence from both behavioral and EEG studies has revealed rhythmic patterns of attentional sampling within or between two locations or objects. In this study, we investigated how attentional rhythms spread across multiple locations in a uniform space. Using a detection task with fine temporal resolution, we found that attentional samplings operate in two distinct rhythms across space. At alpha band, locations were sampled simultaneously along cardinal axes but alternately in ordinal directions with 180° phase lag between central and peripheral regions. Within delta to theta bands, attentional sampling was faster in cardinal than in ordinal directions specifically for peripheral locations. These results show that the distribution of visual attention is nonuniform but

intrinsically organized and encoded in the phase and frequency of diverse sampling rhythms across space, providing a new perspective to understand the spatiotemporal map of visual attention.

Does Depth of Field Attract Attention?

Christina Soderberg and Szonya Durant
Department of Psychology, Royal Holloway, University of London, UK

Across different photographic images and cinematic shots, depth of field often changes. Yet, there is little research to date which indicates the impact on visual attention of these differing depths of field. To determine the impact of depth of field type blur effects on attention, participants were eye tracked while completing a visual search task within a series of natural scene images; to simulate depth of field, one half of each image was randomly selected to be blurred using a Gaussian kernel. Blur intensity was at one of the three levels to approximate the effects of different depths of field. Artificially simulating depth of field type changes using Gaussian blur was not found to influence overall fixation duration distribution on the two halves of the image, meaning there was no clear influence of blur on eye movements overall during visual search. Thus, we find no clear evidence that blur influences attention overall when a search task is given.

Increased Target–Distractor Similarity Reduces Efficient Attentional Selection in Early Visual-Processing Pathways

Frederik Geweke[1] and Viola S. Störmer[2]
[1]Department of Psychology, Humboldt-Universität zu Berlin, Germany
[2]Department of Psychology, University of California, San Diego, CA, USA

Previous research showed that feature-based attention can enhance the color representations at early visual-processing stages. Here, we used electrophysiological recordings of frequency-tagged potentials to investigate how differences in target–distractor similarity influences these attentional modulations. Participants monitored spatially intermingled dot arrays of two colors and detected target events in one of the arrays. Target and distractor colors were either perceptually distinct (180° apart in CIElab color space) or perceptually similar (60° apart). When colors were distinct, sensory signals of the attended color were enhanced, but these attentional modulations disappeared when target and distractor colors were similar. These effects were not due to differences in task performance because performance was matched across conditions. These findings suggest that selection at early visual-processing stages is compromised when targets and distractors are perceptually more similar.

Does Covert Attentional Tracking Operate Over Physical or Perceptual Coordinates?

Marvin Maechler, Patrick Cavanagh and Peter Tse
Department of Psychological and Brain Sciences, Dartmouth College, NH, USA

A static Gabor with a moving internal texture appears to be shifted in the direction of its internal motion, a shift that increases even further if the Gabor itself is in motion. Does attentional tracking of this double-drifting Gabor take place in perceptual coordinates, namely, over apparent positions, or over real position coordinates? Here, subjects had to track one of the three co-orbiting double-drifting Gabors. Depending on the internal drift direction, these could either appear shifted away from or toward one another while maintaining the same real distance. If attentional tracking takes place in perceptual coordinates, tracking performance should be highest (lowest) when the three Gabor patches appear shifted away from (toward) each other. Tracking performance increased with greater perceived distance and decreased with less perceived distance. This suggests that attentive tracking, at least partially, involves operations over consciously experienced, perceptual coordinates.

A Novel Color Singleton on a Surprise Trial Captures Attention Late, Even Under Ideal Conditions

Gernot Horstmann and Daniel Ernst
Department of Psychology, Bielefeld University, Germany

The capturing of attention and gaze by an expectancy discrepant color singleton on its unannounced first (surprise) appearance has been shown to occur in the range of 400 to 600 milliseconds. This seems unusually late as attention capture is often seen as an early attention effect. We ask (a) whether attention capture is generally slow on the first presentation of the capturing stimulus and (b) whether the long latency is due to a weak discrepancy. Experiment 1 demonstrates with a target-similar cue that attention capture is not generally slow on a surprise trial. Experiment 2 presents a "super surprise stimulus" that deviates from expectations on several dimensions and finds latency still in the range of a late latency. Together, the results indicate that the relatively long latency is real. We propose that attention capture by a novel color singleton is slow when

based on expectancy discrepancy and fast when based on preemptive gating of stimuli with specific features.

Biological Motion

Interactions Between Processing Optic Flow and Biological Motion: Evidence From Dual Tasks

Katja Mayer, Hugh Riddell and Markus Lappe
Institute for Psychology, University of Münster

The concurrent processing of optic flow and biological motion is crucial for navigating to a destination without colliding with others. At the neural level, distinct areas have been identified that are specialized in processing each of the two types of motions. It might, therefore, be possible to process both types of motions independently. To test this assumption, we conducted a dual-task paradigm in which we presented a point light walker in a flow field that simulated forward motion. Observers judged both the articulation of the walker and the heading direction. Although accuracy decreased on dual compared to single tasks, varying the difficulty of one task had no effect on the performance of the other task. Training and general dual task effects could not explain the results. Our results argue for independent processing of the two tasks at the sensory level but also for potentially shared resources with respect to cognitive processes at the response level.

Gender Recognition in Point Light Walkers Displays: How Do Experts Compensate Insufficient Kinematic Cues?

Jessica Galliussi[1], Susanna Mezzarobba[2], Michele Grassi[1] and Paolo Bernardis[1]
[1]Department of Life Sciences, University of Trieste, Italy
[2]Department of Medical, Surgical and Health Sciences, University of Trieste, Italy

The ability to recognize gender from biological motion can be based on shape (morphology) or on movement (kinematics), with the latter normally prevailing over the first. We investigated this topic by using real point light walkers stimuli recorded from healthy (H) and Parkinson's disease (PD) volunteers. Sensitivity was measured in nonexperts (psychology students) and experts (physiotherapy students). Results showed that expertise interacts with the type of stimulus: Experts showed a comparable performance with both H and PD stimuli, while nonexperts performed significantly worst with PD stimuli. H and PD stimuli provided same gender-specific morphological cues (shoulder-to-hip ratio) but different gender-specific kinematic cues (torso and pelvic movements), which were preserved only in H stimuli. The results suggest that experts can use morphology to accomplish the task when kinematic cues are insufficient, while nonexperts' judgments rely predominantly on kinematics.

Perception of Biological Motion: No Sensitivity Differences in Patients With Parkinson's Disease

Susanna Mezzarobba[1], Michele Grassi[2], Jessica Galliussi[2], Luigi Murena[1] and Paolo Bernardis[2]
[1]Department of Medical, Surgical and Health Sciences, University of Trieste, Italy
[2]Department of Life Sciences, University of Trieste, Italy

According to Hommel's theory, motor system partially mediates action perception by simulating or embodying observed actions. Previous studies failed to demonstrate motor repertoire compatibility effects, probably because the point light walker (PLW) stimuli used were recorded only from healthy people, and showed that sensitivity to biological motion may be reduced in Parkinson's disease (PD) with motor dysfunction. We hypothesize that perceptual ability in PD patients could be improved by watching PLW of patients with the same disease condition. Two groups of participants (24 healthy and 33 patients with PD) underwent to a gender recognition task with PLW stimuli obtained from healthy and PD actors. The results show a better sensitivity to biological motion in females than males. Moreover, gender recognition has been worsened by watching parkinsonian PLW. Our data do not show a compatibility effect, neither confirm previous data about an impaired perception of biological motion in PD patients.

Incidental Processing of Biological Motion: Effects of Orientation, Local-Motion and Global-Form Features

Vipul Nair, Karl Drejing and Paul Hemeren
School of Informatics, University of Skövde, Sweden

Previous studies on biological motion perception indicate that the processing of biological motion is fast and automatic. A segment of these studies has shown that task-irrelevant and to-be-ignored biological figures are incidentally processed since they interfere with the main task. However, more evidence is needed to understand the role of local-motion and global-form processing mechanisms in incidentally processed biological figures. This

study investigates the effects of local-motion and global-form features on incidental processing. Point light walkers (PLWs) were used in a flanker paradigm in a direction discrimination task to assess the influence of the flankers. Our results show that upright-oriented PLW flankers with global-form features have more influence on visual processing of the central PLW than inverted or scrambled PLW flankers with only local-motion features.

Influence of Crowd Behaviour on Estimates of Biological Motion Speed

Ian M. Thornton[1], Quoc C. Vuong[2] and George Mather[3]
[1]Department of Cognitive Science, University of Malta, Malta
[2]Institute of Neuroscience, Newcastle University, UK
[3]School of Psychology, University of Lincoln, UK

Does the behaviour of to-be-ignored 'crowds' influence the perception of target walker speed? Baseline trials presented two point light walkers that moved at different speeds. The task was to report whether the red or green walker was faster. On experimental trials, the task was the same, but targets were surrounded by five red and five green figures that made two task-irrelevant crowds. On speed-congruent trials, the faster target had a colour-consistent crowd that moved at an even faster pace. On speed-incongruent trials, the colour-consistent crowd moved at a slower pace. There were three possible outcomes: (a) crowd speed congruency could have no influence; (b) averaging of target and crowd speed might lead to faster responses on speed-congruent trials and (c) within-colour contrast between target and crowd might lead to faster responses on speed-incongruent trials. Initial results support the third outcome, suggesting that task-irrelevant crowd speed is processed but not averaged.

The Walker Congruency Effect and Incidental Processing of Configural and Local Features in Point Light Walkers

Paul Hemeren[1], Elizabeth Hanley[2] and Peter Veto[3]
[1]School of Informatics, University of Skövde, Sweden
[2]School of Information, University of Michigan, MI, USA
[3]School of Ophthalmology, University of Cambridge, UK

Two visual flanker experiments investigated the roles of configural and local opponent motion cues on the incidental processing of a point light walker with diagonally configured limbs. Different flankers were used to determine the extent of interference on the visual processing of a central walker. Flankers (walkers) with diagonally configured limbs lacked the local opponent motion of the feet and hands but contained configural information. Partially scrambled displays with intact opponent motion of the feet at the bottom of the display lacked configural information. These two conditions resulted in different effects of incidental processing. Configural information, without opponent motion, leads to changes in reaction time across flanker conditions, with no measurable congruency effect, while feet-based opponent motion causes a congruency effect without changes in reaction time across different flanker conditions. Life detection is a function of both sources of information.

Adaptation to Social Attention: Perception of Social and Nonsocial Cues Differentially Influences Attentional Effect of Biological Motion Walking Direction

Haoyue Ji, Yi Jiang and Li Wang
Institute of Psychology, Chinese Academy of Sciences, China

Social attention is crucial for social interactions and adaptive functioning. However, it remains obscure whether social attention is unique and qualitatively distinct from nonsocial attention. The present study examines the specificity of social attention using visual adaptation technique combined with adapted central cueing paradigm. Results reveal that adaptation to the walking direction of biological motion (BM) affects the reflexive attentional effect induced by BM cues. Critically, this adaptation effect can also be observed when the adaptor is changed to another type of social cues (i.e., eye gaze), reflecting that social attention induced by different types of cues might share common neural substrates. By contrast, such cross-category adaptation effect completely disappears when nonsocial cues (i.e., arrows) are used as the adapting stimuli. These findings provide evidence for the view that "social attention is special" and support the existence of "social attention detector."

Bistable Perception

Age-Dependency in Visual Perceptual Decisions Is Caused by a Variation in Adaptation and Noise, But Not in Inhibition Strength

Richard van Wezel, Raymond van Ee and Elahe Arani
Department of Biophysics, Donders Institute for Brain, Cognition and Behaviour, the Netherlands

The neurobiological mechanisms underlying age-associated changes perceptual decision-making are still elusive. We studied the effect of aging on bistable stimuli in various presentation conditions. Two age groups of participants reported their spontaneous percept switches and mixed percepts during continuous presentation and percept choices during intermittent presentation. We find no significant age effect on the mean and cumulative frequencies of percept switch durations and mixed percepts under continuous presentation. However, the data show a significant age effect on coefficient of variation, ratio of standard deviation to mean of percept durations. Our results also reveal that the alternation rate and percentage of mixed percepts significantly decline at an older age under intermittent presentation. These results suggest that age dependency of visual perceptual decisions is caused by reduced neural adaptation and noise and not by a change in inhibition strength.

Location-Specific Priming of Perceptual Reversals for Kinetic-Depth Effect

Alexander Pastukhov, Christina Rita Zaus and Claus-Christian Carbon
Department of General Psychology and Methodology, University of Bamberg, Germany

Models of multiperception postulate that the alternation rate is determined by the self-adaptation, neural noise, and cross inhibition. The strength of the latter depends on ecological validity of perceptual transformation and prior history, as experience of stability primes stability and vice versa. We looked whether its influence is location-specific by presenting simultaneously two kinetic-depth displays and varying their location between trials (they overlapped, touched, and had a gap in-between) while applying an exogenous trigger to one or both objects. The exogenous trigger was equally effective for all layouts, but closer proximity increased likelihood that both objects would reverse. The priming of perceptual reversals was response-specific (a switch in a single object primed a repeated single switch) and location-specific. This specificity suggests that local mechanisms, rather than a top-down influence, determine switching costs. See https://osf.io/bt3w8.

Individual Variation in Interocular Suppression

Mengxin Wang, Paul McGraw and Timothy Ledgeway
School of Psychology, University of Nottingham, UK

Over the last decade, our understanding of the neural processes underpinning binocular rivalry and interocular suppression have increased markedly, but we have little understanding of the relationship between these two processes and their variation in the general population. To investigate this issue, we compared depth of suppression under conditions of binocular rivalry (BR) with that elicited by continuous flash suppression (CFS), in a group ($N = 21$) of healthy individuals. We found substantial individual variation in the magnitude of suppression evoked by each task, and many individuals showed marked asymmetries between the two eyes' ability to detect a suppressed target that were not necessarily the same for the two tasks. Indeed performance on BR was not a good predictor of performance on the CFS task. The results suggest that the mechanisms driving binocular rivalry and interocular suppression may be, at least, partially distinct and that sensory eye dominance is task dependent.

BR-OKN Responses Reveal Fine Tuning of the Developing Visual System During Adolescence

Gergő Ziman[1], Stepan Aleshin[2], Péter Soltész[1], Jochen Braun[2] and Ilona Kovács[1]
[1]Institute of Psychology, Pázmány Péter Catholic University, Hungary
[2]Institute of Biology, Otto-von-Guericke University, Germany

In earlier studies of binocular rivalry (BR) development, we found higher reversal rates in children and adolescents compared to adults, indicating increased readiness for adaptation. Here, we confirm and extend these results with two innovations: (a) we reconstruct the dynamical balance of perceptual adaptation, inhibition, and noise in terms of a computational model and (b) we establish reversal statistics from ocular responses rather than volitional reports. We establish adaptation, inhibition, and noise parameters in 12- and 16-year-old children and young adults, finding consistent differences in adaptation. In terms of dynamical regime, perception moves from a more "stable" mode, where reversals are more susceptible to noise, to a more "sensitive" mode, and to input modulation. We conclude that these changes reflect fine tuning and maturation of the developing visual system during adolescence. This study was funded by NKFI, NN110466, and DFG BR987/3.

How Much Evidence Do We Need for a Smile? ERP Correlates of Emotional Ambiguity

Ellen Joos[1], Anne Giersch[1], Ulrich Schaller[2], Reinhold Rauh[2], Volker Helzle[3], Ludger Tebartz van Elst[4] and Jürgen Kornmeier[5]
[1]INSERM U1114, Cognitive Neuropsychology and Pathophysiology of Schizophrenia, University of Strasbourg, France
[2]Department of Child and Adolescent Psychiatry, Psychotherapy, and Psychosomatics, Medical Center—University of Freiburg, Germany
[3]Animationsinstitut, Filmakademie Baden-Wuerttemberg, Germany
[4]Department of Psychiatry and Psychotherapy, Medical Center—University of Freiburg, Germany
[5]Perception and Cognition Group, Institute for Frontier Areas of Psychology and Mental Health, Germany

We recently found smaller amplitudes of two event-related potential (ERP) components when participants observed ambiguous stimuli compared to disambiguated stimulus variants ("ERP Ambiguity Effect"). In the current study we tested, whether an ERP Ambiguity Effect also occurs with ambiguity in emotional face expressions (happy-sad-axis). In two experiments, we used face stimuli with minimal (smileys) and maximal emotion cues (full faces).We found equally large ERP Ambiguity Effects for both smileys and full faces. Furthermore, we found a sustained negative electroencephalogram (EEG) shift with full faces, starting already at 100 milliseconds and lasting for 300 milliseconds, and longer reaction times (RT) compared to smileys. Interpretation: The ERP Ambiguity Effect reflects high-level reliability estimation of perceptual outcomes. Maximal emotion cues (full faces) increase the processing costs (negative shift of EEG traces and longer RTs), even though minimal emotion cues (smileys) are sufficient for maximal perceptual reliability (equal ERP Ambiguity Effect).

Breaking Down the Break in Continuous Flash Suppression

Florian Kobylka, Malte Persike and Günter Meinhardt
Institute of Psychology, Section Methods and Statistics, Johannes Gutenberg-University Mainz, Germany

Continuous Flash Suppression (CFS) is a variety of binocular rivalry, whereby a dynamic noise masker presented to one eye suppresses perception of a stimulus presented to the other eye. We examined temporal characteristics of the transition into conscious perception in the first break of CFS, increasing contrast of the suppressed stimulus at different rates (100%/50%/25% per seconds). Presentation was terminated when fixed contrasts were reached. Subjects judged stimulus position (left/right from fixation) and type (face/house). Performance in both tasks depended on contrast but not on the temporal contrast gradient. In a binocular control task, performance improved when contrast changed at slower temporal rates. Also the shape of psychometric curves was quite different for CFS and control task. The findings indicate that signal strength is more crucial for breaking CFS than integration of sensory input over time. This suggests qualitatively different transitions in CFS and binocular control.

The Variety of Perceptual Transitions During Binocular Rivalry

Alexandra Sipatchin[1], Natalia Zaretskaya[2] and Andreas Bartels[1]
[1]Vision Lab, Centre for Integrative Neuroscience—University of Tübingen, Germany
[2]Institute of Psychology, University of Graz, Austria

Studies involving magnetic resonance spectroscopy, alcohol intake and neuropsychiatric disorders such as autism and attention-deficit/hyperactivity disorder have recently linked perceptual transitions during binocular rivalry to inhibition in the visual system. In these studies, transitions are regarded as a single, clearly defined perceptual event. Here, we questioned this assumption by systematically investigating perceptual transitions during binocular rivalry in healthy individuals. We found that most observes perceive at least four transition categories when viewing orthogonal gratings and three categories when viewing a face-house images. In addition, we observed that manipulating the contrast of gratings affects not only the duration of transitions but also the relative frequency of different transition types. Our study for the first time confirms that perceptual transitions in binocular rivalry are heterogeneous and points towards the necessity to distinguish between different transition types in future binocular rivalry studies.

Task Dependence of Reversal-Related ERP Components in Perception of the Necker Lattice

Diane Abdallah[1] and Joseph L. Brooks[2]
[1]Department of Psychology, University of Kent, UK
[2]School of Psychology, Keele University, UK

Perceptual multistability is characterized by alternating interpretations of an unchanging stimulus input. To investigate top-down and bottom-up neural processes involved in endogenous perceptual reversals, we measured the Reversal Negativity (RN) and the Reversal Positivity (RP)

event-related potentials components under two different task conditions. In the standard reversal task, participants indicated whether or not they saw a perceptual reversal on each trial. In contrast, in the identity task, participants reported perceived orientation of the stimulus without any reference to reversals. We found that the RN component appeared independently of task, whereas the early latency RP component was not present during the identity task despite equivalent numbers of reversals in this task. Our results suggest that the early RP component depends critically on top-down monitoring for reversals and thus is not a neural signature of pure bottom-up stimulus processes related to endogenous perceptual reversals.

The Link Between Blinks, Microsaccades and the Percept of Bistable Motion

Mareike Brych, Supriya Murali, Liyu Cao and Barbara Haendel
Department of Psychology III, University of Wuerzburg, Germany

Small eye movements such as microsaccades and blinks have been suggested to have perceptual consequences. To further investigate the link between eye movements and perception, we used an ambiguous plaid stimulus, which can be perceived either as coherent diamond movement or as incoherent stripe movement. We found blinking as well as blanking of the screen to be associated with an increased probability of coherent motion percept followed by a decreased probability of incoherent motion percept. The temporal evolution, however, differed between blink and blank. Interestingly, our data further show a temporal link between microsaccades and blinks, revealing a pronounced increase in microsaccade rate after the blink. Our findings suggest that eye movements have a specific influence on the perceptual interpretation of ambiguous stimuli which goes beyond the previously suggested undirected triggering of a perceptual switch.

Clinical

The Relation Between the Degree of Synaesthesia, Autistic Traits, and Local/Global Visual Perception

Floor Burghoorn[1], Rob van Lier[2] and Tessa M. Van Leeuwen[2]
[1]Faculty of Social Sciences, Radboud University, the Netherlands
[2]Donders Institute for Brain, Cognition and Behaviour, Radboud University, the Netherlands

The current study investigated the relation between autistic traits (measured by the autism spectrum quotient) and the degree of synaesthesia in neurotypicals ($N = 36$), as well as whether this relation might be formed by a shared bias toward local (detail-focused) visual perception. Preliminary analyses demonstrated a positive correlation between AQ scores and the degree of synesthesia. Our study hereby extends on previous studies that have shown a high autism spectrum disorder (ASD)-synesthesia co-occurrence in clinical populations. Furthermore, and consistent with the hypothesized local bias in ASD, AQ scores were related to increased performance on an embedded figures task as well as to reduced susceptibility to visual illusions. However, no relation between synesthesia and local visual perception could be found. This suggests that the relation between the degree of synesthesia and autistic traits in neurotypicals might be formed by a mechanism other than the hypothesized shared bias toward local visual perception.

Holistic Word Processing in Dyslexia

Nuala Brady, Sarah Cooney, Kate Darmody, Michael Horgan and Fiona Newell
Department of Psychology, Trinity College Dublin, Ireland

Although most commonly associated with deficits in phonological processing, recent research also implicates anomalous orthographic processing in dyslexia. In this study, students with dyslexia completed a 'composite words task' designed to test for holistic processing of familiar short words. Participants judged whether the left or right halves of a sequentially presented pair of four-letter words were the same (or different) across trials varying in congruency and alignment. On congruent trials, both the attended and unattended halves of the two words were the same (or different), whereas on incongruent trials, the attended and unattended halves were mismatched. Additionally, the word pairs were aligned or vertically displaced in space. While participants with dyslexia were sensitive to congruency, their response times were much slower than those of controls and less reliant on the spatial alignment between the word pairs, suggesting a greater reliance on analytic processing in dyslexia.

Metacognition Mediates Relationship Between Temperamental Traits and Hallucination Proneness in General Population

Remigiusz Szczepanowski and Ewelina Cichoń
Faculty of Psychology in Wroclaw, SWPS University of Social Sciences and Humanities, Poland

Recent studies based on regression have demonstrated significant relations between temperament traits, hallucinatory-like experiences, and metacognition in normal population. However, casual indicators explaining relations between these psychological variables remain still unclear. We used structural equation modeling to perform in-depth investigation of these relationships. Our questionnaire study examined whether dysfunctional metacognitive beliefs mediated the relationship between temperamental and hallucinatory-like experiences in healthy participants ($N = 205$). The mediation analyses using structural equations and bootstrapping technique were performed. Our results showed that impact of temperamental trait such as emotional reactivity on hallucination proneness was mediated by negative beliefs about uncontrollability and danger of thoughts and positive worry beliefs. We tentatively suggest that temperament affects hallucination proneness via metacognition in healthy population.

Visual Acuity and Contrast Sensitivity Depending on Keratoconus Apex's Position

Sanita Liduma and Gunta Krumina
Department of Optometry and Vision Science, University of Latvia, Latvia

The optical quality of the vision is influenced by changes in corneal shape in keratoconus patients; therefore, both high degree ocular and corneal aberrations are significantly higher compared to a normal patient's eye. The goal of our study was to find a correlation between the position of keratoconus corneal apex, visual acuity and contrast sensitivity. Study includes 79 patients' eyes, graded from first to third keratoconus stages. Visual acuity and contrast sensitivity were measured at 3-m distance with and without the best possible spectacle correction using FrACT software (version 3.9.3.). The data acquired as a result of our study show that for keratoconus patients from normal contrast sensitivity, a deviation begins at medium 5 cpd frequency. Spectacle correction statistically significantly changes contrast sensitivity at lower spatial frequencies in patients who have apex at the center compared to apex being located on the periphery, with or without spectacle correction.

Evaluating the Ergonomics of a Virtual Reality Software for the Diagnosis and Treatment of Amblyopia

Johann Schneider[1], Juliane Tittes[2], Maria Fronius[2], Peggy Feige[2], Yaroslava Wenner[2], Robert Hess[2] and Jochen Triesch[1]
[1]Department of Neuroscience, Frankfurt Institute for Advanced Studies, Germany
[2]Department of Ophthalmology, Goethe University Hospital, Germany

Virtual Reality (VR) is a promising technology for assessment and treatment of vision disorders. We have developed a VR software for the diagnosis and treatment of amblyopia comprising a stereo acuity test, two interocular suppression tests, and an arcade-like treatment game. In a pilot study, 11 adult participants (6 amblyopic, mean age: 24 years; 5 normal, mean age: 26 years) evaluated the software and compared it to standard clinical stereo and suppression tests using a questionnaire. Although subjects were inexperienced in VR and video games, they familiarized rapidly with the software and described it as easy to use. Most (9/11) subjects reported eye fatigue, neck pain, or headache but still tended to prefer the VR tests over the clinical tests. We conclude that VR may represent a convenient and inexpensive alternative to standard clinical assessment procedures. Supported by the ERA-NET NEURON Cofund network.

Probing Visual Field Integrity Using an Anatomical Measure of the Stria of Gennari at Ultra-High Field MRI

Carlien Roelofzen[1], Alessio Fracasso[2], Douwe Bergsma[3], Giorgio Porro[4], Mies van Genderen[5], Serge Dumoulin[6] and Natalia Petridou[7]
[1]Department of Experimental Psychology, Utrecht University, the Netherlands
[2]Institute of Neuroscience and Psychology, University of Glasgow, Scotland
[3]Donders Institute for Brain, Cognition and Behaviour, Radboud University Nijmegen, the Netherlands
[4]Department of Ophthalmology, University Medical Center Utrecht, the Netherlands
[5]Bartiméus Institute for the Visually Impaired, the Netherlands
[6]Spinoza Centre for Neuroimaging, Royal Netherlands Academy for Arts and Sciences (KNAW), the Netherlands
[7]Department of Radiology, University Medical Center Utrecht, the Netherlands

Visual input from the retina reaches primary visual cortex at the level of the highly myelinated stria of Gennari. Using ultra-high field magnetic resonance imaging (7 T), it is possible to visualize myelin distribution at a submillimeter resolution and visualize the stria of Gennari in vivo in humans.

Here, we hypothesize that myelin content covaries with loss of visual input. We mapped myelin in participants with visual field defects or absolute visual scotomas and evaluate whether the clinical symptoms are reflected in myelination in the occipital cortex, testing for an anatomical measure of visual field sensitivity. The stria of Gennari and global myelination are not modulated by the presence of a scotoma. The stria of Gennari is not a good marker for visual input integrity. These results suggest that hard-wired developmental mechanisms forming the stria of Gennari are completed after development and are not modulated by a sudden change in the functional response of the visual system.

Bilateral Visual Field Maps in a Patient With Left Eye Microphthalmia and Massive Congenital Brain Damage Involving the Left Geniculostriate Pathway: A Case Study

Akshatha Bhat[1], Jan W. Kurzawski[1], Giovanni Anobile[1], Francesca Tinelli[1], Laura Biagi[1] and Maria Concetta Morrone[2]
[1]IRCCS Stella Maris Foundation, Italy
[2]Department of Translational Research on New Technologies in Medicine and Surgery, University of Pisa, Italy

Impairment of geniculostriate pathway results in scotoma in the corresponding part of the visual field. Here, we present a case of a patient with left eye microphthalmia and with lesion of most of her left geniculostriate pathway including lateral geniculate nucleus (LGN). Despite the severe lesions, the patient has complete vision in the 15° of central visual field. Probabilistic tractography demonstrated the absence of optic radiations to left striate cortex and also reveals the altered connections from optic chiasm to left superior colliculus and then to left MT. Population receptive field mapping of patient's visual field reveals consistent contralateral retinotopic map in the left and in the right hemisphere, despite the complete lesion of one LGN. Interestingly, we also revealed retinotopic maps of ipsilateral visual field in the right hemisphere, previously observed in other congenital hemianopia patients. Our results indicate an astonishing case for flexibility of the developing retinotopic maps.

A New Optogenetic Strategy: Recovering From Blindness With Simulated Transfected Vision in Ecological Conditions

Mylene Poujade and Ryad Benosman
Department of Vision and Natural Computation, Institut de la Vison, France

The retinitis pigmentosa is a genetic eyes disorder leading to the degenerescence of photoreceptors with a progressive loss of peripheral vision. A curative strategy based on optogenetic is currently developing. It consisting in the re-expression of the photosensitive protein involved in the photoreceptors sensitivity. Before testing the optogenetic therapy in human patients, the simulated vision is studied on 12 healthy subjects thanks to stimulation google. We tested three transfected rates (15%, 45% and 100%) to evaluate it impact in daily ecological situations: reaching static objects, locomotion tasks (following of ground lines, door crossing) as well as letters recognition and shapes and gender of faces discrimination. Hit rates and reaction times are recorded as well as subject movements via motion capture for locomotion tasks. We found that those tasks are achievable with this simulated optogenetic strategy and that the performances increase with the transfected rate.

Study of Cerebral Visual Perception Impairment Before and After Surgery in Strabismus

Yongchuan Liao[1] and Li Yan[2]
[1]Ophthalmology Department, West China Hospital Sichuan University, China
[2]Guangdong Institute of Medical Instruments, Guangdong Academy of Sciences, China

Strabismus surgery is used to correct the anatomical eye position clinically; we develop a novel VR binocular vision method to measure and access the changes and recovery condition after operation. Eighty-seven strabismus cases before surgery and 145 cases after surgery, aging 4–10, were examined for strabismus angle routinely and then measured and accessed the binocular visual function using two binocular visual perceptual model via a polarization display, including binocular alignment model and stereopsis model. There is a positive correlativity on binocular horizontal alignment deviation and coarse dynamic stereopsis between preoperation and postoperation, but no correlativity on binocular vertical alignment deviation. We can infer that as the visual cortex disrupted by the occurrence of strabismus remain not recover, the patients should go further plastically training after surgery.

Long-Term Improvement of Spatial Attention in Chronic Stroke Patients: A TMS Study

Sara Agosta[1], Denise Magnago[1], Emanuela Galante[2], Francesco Ferraro[2], Francesca Girelli[2], Nunzia Mazzini[3], Emily Grossman[4] and Lorella Battelli[1]
[1]Fondazione Istituto Italiano di Tecnologia—Center for Neuroscience and Cognitive Systems, University of Trento, Italy
[2]S.C. Riabilitazione Specialistica Neuromotoria, Azienda Socio Sanitaria Territoriale di Mantova, Italy
[3]Medicina Fisica e Riabilitazione, Azienda Provinciale per i Servizi Sanitari di Trento, Italy
[4]Department of Cognitive Sciences, University of California Irvine, CA, USA

It is well known that chronic right parietal patients (cRPP) present with deficits in spatial computations in the left visual field. These deficits are a consequence of an increased inhibition exerted on the damaged hemisphere by the hyperactive unaffected one. Previously, we found improvement in sustained attention in the contralesional field in cRPP, after a single 1 Hz-transcranial magnetic stimulation (TMS) session. In the present study, we sought to extend this effect in time and to compare it to alternative behavioral training with no stimulation. We tested two groups of cRPP: active and sham TMS. We asked patients to complete a bilateral multiple-object tracking task 3 times: at baseline, after 5 days of rTMS and at follow-up after 1 week. In a control experiment, another group of cRPP trained on the same task with no stimulation. Only patients in the active TMS group improved in the left field after TMS. The improvement lasted at least 1 week after stimulation and no effect of behavioral training was found.

The Desynchronization of the Interaction Magnocellular and Parvocellular Visual Pathways Is the Biomarker of Stress

Irina Shoshina[1], Ekaterina Zavyalova[2], Roman Sergienko[3], Andrey Gruzdev[3], Ekaterina Potapova[2], Tatiana Skutina[2], Elena Fedorenko[2] and Valeria Karpinskaia[4]
[1]Pavlov Institute of Physiology, Russian Academy of Sciences, Russia
[2]Department of Psychology, Siberian Federal University, Russia
[3]Department of Philosophy, Siberian Federal University, Russia
[4]Department of Psychology, St. Petersburg State University, Russia

The aim of this study was to examine the functional state of magnocellular and parvocellular visual pathways in a professional burnout. We measured the contrast sensitivity. The magnocellular system is most sensitive to low spatial frequency, parvocellular system, to high spatial frequency. The participants with the resistance phase at a formative stage and participants with symptoms of formed resistance phase demonstrated increased contrast sensitivity at low spatial frequencies compared to individuals without burnout. Compared with individuals without burnout, participants with symptoms of formed resistance phase had reduced contrast sensitivity at medium and high frequencies. Also, participants with symptoms of formed resistance phase showed reduced contrast sensitivity at medium and high spatial frequencies compared with participants with the resistance phase at a formative stage. We propose to consider the functional state of magno- and parvosystems as a biomarker of chronic stress.

Visual Social Reasoning in Females With Mastocarcinoma Is Impaired by Negative Gender-Related Messages

Alexander N. Sokolov[1], Marina Pavlova[2], Diethelm Wallwiener[1], Sara Y. Brucker[1] and Elisabeth Simoes[1]
[1]Women's Health Research Institute, University of Tübingen Medical School and Hospital, Germany
[2]Department of Psychiatry and Psychotherapy, University of Tübingen Medical School and Hospital, Germany

Negative messages affect visual social reasoning, especially in women. This effect may also occur in female patients blocking their coping with disease. Here, the influence of negative gender-related messages on performance in a visual social reasoning task was studied in breast cancer (BC) patients. Two groups of patients ($n = 40$) and two groups of matched healthy controls ($n = 40$) completed the task either with standard instruction or with additional negative gender-related information ("men are commonly better on the task"). Negative messages yielded the lowest scores in patients compared to both controls and patients with standard instruction. The findings show for the first time hampering effects of negative messages on social reasoning abilities in BC patients. Future research will reveal the brain mechanisms underlying these effects for enhanced care-related social cognition, reasoning, and decision-making in BC patients.

Foveal Motion Thresholds and Response Variability in Glaucoma

Lorenzo Scanferla, Catarina A. R. João and Nomdo M. Jansonius
Department of Ophthalmology, University Medical Center Groningen, the Netherlands

For motion stimuli presented peripherally, abnormal psychometric curves were found in glaucoma. The aim of this study was to compare foveal motion thresholds and response variability between glaucoma patients and controls under photopic and mesopic conditions. Threshold amplitude for an oscillating line (1.2 arcmin; 0.5–10 Hz) was measured using a Bayesian adaptive method. Psychometric slope and threshold were estimated simultaneously for a subset of stimuli. Glaucoma subjects showed elevated thresholds for all conditions. In both groups, a reduction in luminance resulted in a more shallow slope and elevated threshold. Response variability was similar in both groups, particularly under mesopic light levels. Foveal motion processing deficits are present in glaucoma. Similar psychometric slopes in both groups differs from what has been reported before and could indicate a difference between foveal and peripheral vision.

Comparison of White/Gray Flicker Matrices for P300 Brain–Computer Interface

Cristian Postelnicu, Daniel Voinea and Florin Girbacia
Department of Automotive and Transport Engineering, Transilvania University of Brasov, Romania

The objective of this study was to determine which combination of white and gray gradients is most suitable for the presentation of P300 visual stimuli in a spelling task while using the Oculus Rift headset. The white color displayed on the headset can create a bleeding effect which might disturb the users while focusing on the flashing stimuli. Three combinations were chose for the online tests for the dark and flash states: gray64—white (C1), gray64—gray192 (C2), and gray64—gray128 (C3). The numbers for gray gradients corresponds to the RGB color having the same value within a range between 0 and 255. Tests were conducted with five users each one being required to spell a six characters long text. The highest mean accuracy rate was of 90% for C2, while the two others were of 83.33% for C3 and 73.33% for C1. This work was supported by a grant of the Ministry of National Education and Scientific Research, RDI Programme for Space Technology and Advanced Research—STAR, project number 566.

Colour

Investigating the Effects of 'Colour-Correcting' Glasses on Chromatic Discrimination

Cat Pattie, Thomas Le Couteur-Bisson and Gabriele Jordan
Institute of Neuroscience, Newcastle University, UK

Optical aids for red–green colour vision deficiencies (CVD) are becoming increasingly popular. Our aim was to provide empirical evidence for the effectiveness of such aids to improve chromatic discrimination. Following CVD classification, participants performed the Farnsworth-Munsell 100-Hue test (FM-100) and Ishihara plates with and without EnChroma glasses. The testing area was illuminated by natural daylight and a light source equivalent to D65. A 30-minute adaptation period wearing the glasses was imposed. Preliminary analyses of 28 anomalous trichromats (16 Da, 12 Pa), 6 dichromats (2 D and 4 P) and 24 control participants indicate no change in error scores for any CVD subgroup on FM-100, but a significant increase in errors for normal controls, $F(2, 55) = 8.920$, $p = .004$. There was no change in error score for Ishihara Plates for any group, $F(2, 55) = 2.595$, $p = .113$. The study is ongoing and a theoretical model will be provided to explain the results.

Basic Color Terminology Expansion—Evidence From Serbian

Ivana Jakovljev[1] and Sunčica Zdravković[2]
[1]Department of Psychology, University of Novi Sad, Serbia
[2]Department of Psychology, University of Belgrade, Serbia

We investigated cognitive salience of Serbian color terms to establish a preliminary list of basic color terms (BCTs) in order to identify the evolutionary stage of the Serbian language according to the universalistic BCTs theories. In a color-elicitation task, participants (83) had to list as many color terms during 5 minutes. On average, 16.7 terms were listed. Based on collected measures for each term (frequency, mean position, and two cognitive salience indexes), we isolated 10 BCTs (excluding brown), which places the Serbian language on the highest evolutionary stage (Stage VII). However, 5 additional terms (including brown) showed higher salience, indicating that BCT inventory might be expanding to include 15 terms. This supports relativistic viewpoint suggesting that basic color terminology is not restricted to 11 universal terms but is evolving due to communication needs. This research was supported by Ministry of Education and Science, Republic of Serbia (grant:179033).

Discrimination Boundaries for Skin Stimuli

Tushar Chauhan and Sophie Wuerger
School of Psychology, University of Liverpool, UK

Recently, discrimination boundaries akin to MacAdam ellipses for uniform colours have also been characterised for natural stimuli such as foliage and fruit. Here, we present an estimation of discrimination boundaries for another important class of natural stimuli – human skin. The measurements were made under simulated daylight and artificial fluorescent lighting, with discrimination boundaries being estimated in a chromatic-luminance space. We show that the discrimination volumes for skin and skin-like stimuli are consistently higher than those for uniform colour. We also show that chromatic discrimination ellipses for these stimuli are modulated by both the ambient illumination and the colour of the stimulus, with the area being proportional to the chromatic distance of the stimulus from the illuminant. Our findings place human skin in the same class as important natural polychromatic stimuli such as green foliage and red fruit.

ERP Responses to the Perception of Glossiness of the Basic Colors

Tatsuya Yoshizawa[1], Haruyuki Kojima[2], Tomohisa Matsumoto[3], Masayuki Sato[4] and Keiji Uchikawa[3]
[1]Department of Human Sciences, Kanagawa University, Japan
[2]Department of Psychology, Kanazawa University, Japan
[3]Research Institute of Multimodal Sensory Science, Kanagawa University, Japan
[4]Department of Information and Media Engineering, University of Kitakyushu, Japan

We intuitively recognize gold as a special color being different from other basic colors or other glossy colors such as a glossy green. Despite this general cognitive aspect, our previous study of whether gold was different in visual properties when compared with other glossy colors showed no psychophysical difference. This indicates that gold is just glossy yellow. Therefore, to figure out a missing connection between these facts as a first step, we measured event-related potential (ERP) responses to a glossy and a nonglossy color in the oddball paradigm. We tested on four basic colors. We found significant different ERP responses between the glossy and nonglossy color in sensors corresponding to the visual cortical areas, but no significant difference among the four colors. These suggested that there is no visual mechanism to perceive a specific glossy color and that a cortical mechanism in higher stage beyond early visual mechanisms produces cognitive difference between gold and other glossy colors.

Stronger Colour Induction in Migraine

Xavier Otazu[1], Nilai Sallent[1], Xim Cerda-Company[1] and Olivier Penacchio[2]
[1]Department of Computer Science, Computer Vision Center, Spain
[2]Department of Psychology and Neuroscience, University of St Andrews, UK

Excitatory–inhibitory neural mechanisms play an important role in colour perception. In particular, lateral connections are thought to underlie chromatic induction, the change in colour appearance of a central location caused by surrounding light. On the other hand, there is growing evidence that individuals with migraine have an excitation–inhibition imbalance. We measured colour induction in migraine with (MA) and without aura (MO) as well as controls ($n = 7$ for each group) using striped and uniform surroundings. We found significant differences in colour induction between migraine sufferers and controls. Colour induction, both contrast and assimilation, was, respectively, stronger for the MO group than for the MA group and for the MA group than for controls. The differences were more marked in the 's' than in the 'l' direction. These preliminary results further support the hypothesis that migraine involves an imbalance of cortical excitation and inhibition.

The Effect of Object Shapes on Color Categories Judgment

Hyejin Han
Division of Design, Incheon National University, South Korea

The purpose of this study is to define the color categories in Republic of Korea. In addition, the effect of object's shapes on the judgment of color categories was researched. Firstly, Korean basic color terms were investigated. The results were included 11 basic color terms (ppalgang/red, cholog/green, nolang/yellow, bola/purple, geomjeong/black, palang /blue, juwhang/orange, hayang/white, bunhong/pink, galsaeg/brown, and hoesaeg/gray) with four additional terms: namsaeg/dark blue (indigo), yeondu/yellow-green (pea), haneulsaeg/light blue (sky blue), and salgusaeg/apricot (skin). Secondly, using colors of the higher response frequency, the effect of shape of objects, associated with the colors (red/apple, green/leaf, yellow/forsythia, and purple/grape), on the range of color categories was researched. As a result, different ranges were showed on each color categories depending on shapes. Therefore, it can be suggested the shape of objects effect on the judgement of color categories.

Italian 'Blue' Categories: Colour Space Mapping Manifests the Diatopic Name Variation

Galina Paramei[1], Mauro D'Orsi[2] and Gloria Menegaz[2]
[1]Department of Psychology, Liverpool Hope University, UK
[2]Department of Computer Science, University of Verona, Italy

Standard Italian has more than one 'blue' basic colour term: Blu is unanimously glossed as 'dark blue'; azzurro, however, is referred to as 'light blue' or 'medium blue'. We explored diatopic variation in denotata of blu, azzurro and celeste 'sky blue' in a psycholinguistic experiment conducted in Verona (Veneto region) and Alghero (Sardinia). Participants named Munsell chips ($N = 237$) of the BLUE area. For each 'blue' term, a referential volume of colours with naming consensus was fitted by a convex hull visualised in CIELAB space. We found that the referential extents of azzurro and celeste differ markedly between the two regions: Verona speakers denote 'light-and-medium blue' by azzurro; in contrast, Alghero speakers use mainly celeste for the same extent. Conceivably, the contact-induced prominence of celeste for the latter was reinforced by the insularity and conservatism of the Algherese Catalan dialect to the detriment of the low-consensus usage and referential extent of azzurro.

An Experimental-Phenomenological Research on the Mode of Appearance of Color Seen Through the Superposed Two Punching Plates

Atsushi Sakai
Department of Psychology, Meisei University, Japan

Observers looked some interference patterns made by superposing a punching plate with multiple circular holes on another punching plate against colored background. When the gradient of aperture size made by superposition was steep, it was perceived as something like floral pattern, and it appeared as a surface color. If the gradient of aperture size is gentle, observers perceived something spherical and soft, and it appeared as a film color. Under this condition, if the distance between two superposed plates was increased or the front plate was moved horizontally back and forth, the appearance as a volume color grew more certain. Kanizsa pointed out that the edge of the surface has an influence on how the enclosed surfaces appear. That is, if the edge is clear, the surface appears solid or hard, and if the edge is blurred outward, the surface appears cloudy or soft. The similarity between those phenomena was also examined.

Assessing the Effectiveness of Notch Filters for Enhancing Anomalous Colour Vision

Lucy Somers, Anna Franklin and Jenny Bosten
Department of Psychology, Sussex University, UK

EnChroma Inc. has developed glasses that are claimed to enhance the colour vision of anomalous trichromats. However, the limited evidence available indicates that the glasses have no significant effect on performance on tests for colour vision deficiency. We predicted the effects of the glasses on a broader range of stimuli using models of anomalous vision. We modelled the impacts of multiple EnChroma products on the appearances of broadband reflective surfaces (e.g., Munsell surfaces) under a range of illuminants (e.g., halogen, LED, and incandescent) and on the appearances of narrowband (RGB) stimuli. For broadband stimuli, all combinations of EnChroma product and illuminant resulted in gamut expansion along the protan and deutan confusion axes. For narrowband stimuli, the predicted effects were mixed: In some instances. there was no effect, or even gamut contraction. We present the results of our models, along with psychophysical data collected in order to validate them.

Colour-Evoked ERPs Reflect Chromatic and Luminance Content of the Stimulus Rather Than Its Hue Category

Jasna Martinovic[1], Sophie Wuerger[2], Tushar Chauhan[3] and Lindsay Thompson[1]
[1]Department of Psychology, University of Aberdeen, UK
[2]Department of Psychology, University of Liverpool, UK
[3]CerCo, University of Toulouse, France

Colour-evoked event-related potentials (ERPs) may be influenced by low-level factors such as chromatic and luminance contrast or high-level factors such as hue category. We assessed if ERPs are more sensitive to low or high-level factors in a study that used two unique (red and green) and two nearby non-unique hues (orange and turquoise) at three levels of luminance: nominally isoluminant, 45% and 90% luminance contrast. A coloured circle was displayed, changing its shape into a square or a diamond. We analysed ERPs at stimulus onset and at shape change, finding that red and orange drove different waveforms than green and turquoise at isoluminance, in line with similarities in cone-opponent content. Addition of luminance led to drastic changes between 90 and 300 milliseconds for all colours, with the waveforms becoming more uniform. Our findings indicate that ERPs 90 to 300 milliseconds post-stimulus predominantly reflect low-level, chromatic and luminance contrast and are thus not suitable for the study of categorical colour vision.

Luminance and Chromatic Contrast Sensitivity at High Light Levels

Maria Perez-Ortiz[1], Jasna Martinovic[2], Rafal Mantiuk[1] and Sophie Wuerger[3]
[1]Department of Computer Science and Technology, University of Cambridge, UK
[2]The School of Psychology, University of Aberdeen, UK
[3]Institute of Psychology, Health and Society, University of Liverpool, UK

Contrast sensitivity functions (CSF) are commonly used to characterise the sensitivity of the human visual system at different spatial scales, but little is known about CSF at light levels reflecting everyday outdoor vision. The purpose of our study was to measure chromatic CSF at medium and high luminance levels (100, 1,000 and 7,000 cd/m^2). Stimuli were displayed on a high dynamic range display allowing background luminance levels of up to 15,000 cd/m^2. Also, 0.5° Gabor patches were generated; stimulus placement and threshold estimation were controlled using a four-alternative forced choice procedure (Quest; PsychToolBox). CSF were measured in three directions in colour space, reflecting early post-receptoral processing stages: an achromatic (L + M) direction, a 'red–green' (L/(L − M)) direction, and a 'lime-violet' direction (S/(L + M)). Our preliminary results suggest that the shape of the chromatic CSF is changing when the background luminance is increased from 100 and 7,000 cd/m^2. Local and global adaptation models will be discussed.

The Program Simulating Dichromacy as a Possible Tool for Detecting Color Deficiencies

Paul Maximov
Laboratory of Sensory Information Processing, Institute for Information Transmission Problems of the Russian Academy of Sciences, Russia

A normal human color vision is based on three types of cones with L, M, and S photopigments. The absence of one of them results in dichromacy: protanopia (−L), deuteranopia (−M), and rare tritanopia (−S). There were many applications developed to make a normal trichromate understand how the dichromates perceive colors, generating a single picture for each form of dichromacy. However, there are an infinite number of images indistinguishable from the original one. My program converts the input picture by direct and inverse transformations between monitor pixel values (R, G, and B) and relative cone excitations (L, M, and S), depicting it in various "palettes." All three images (original, "deuteranopic," and "protanopic") are presented simultaneously. The subject under test must choose one picture differing in color from the other two. Normal trichromates select the original picture as the most different one, protanopes select "deuteranopic" image, and deuteranopes select "protanopic" image.

Tablet-Based App for Screening for Colour Vision Deficiencies in Young Children

Leticia Álvaro, James Alvarez, Brenda Meyer, Teresa Tang, John Maule, Anna Franklin and Jenny Bosten
School of Psychology, University of Sussex, UK

There is currently no widely available and accurate test for diagnosing colour vision deficiency (CVD) in pre-literate children, yet young children with CVD may be particularly disadvantaged by widespread use of colour in early learning environments. We present a new tablet-based app that is aimed as a tool for screening for CVD in children aged 2 to 6 years. The app measures chromatic thresholds along protan, deutan and tritan confusion lines using an adaptive staircase procedure. Targets are coloured discs presented on a grey surround, with both luminance and tritan noise included to increase sensitivity. The test is embedded in a child-friendly interface 'game' where children reveal characters by correctly selecting the coloured targets. We are able to achieve accurate colour calibration on Apple iPads, with errors along the MacLeod-Boynton L/(L + M) axis under 0.5% and maximum tritan errors of 3% (which are masked by the tritan noise). We present preliminary results from a population of 4- to 7-year-old children.

Effects of Reflecting and Sub-Surface Scattering Lights on Facial Skin Appearance

Katsunori Okajima and Yuna Nakanishi
Faculty of Environment and Information Sciences, Yokohama National University, Japan

The light enters the skin is reflected, propagated, absorbed and diffused in each layer. We examined the effects of reflecting and sub-surface scattering lights on facial skin appearance and how we evaluate the skin quality. We measured the reflecting and the scattering components of nine women's faces by applying Nayer's method and generated artificial average faces which had different ratios of the reflecting and the scattering components. Participants evaluated healthiness, preference, skin transparency, luster and whiteness of each face. The results show that the optimal ratios of both components for skin transparency depend on individuals. We found that skin transparency can be explained by a function of three variables: luster, whiteness

and see-through sensation, and that preference of skin appearance can be estimated by an equation with two variables: individual healthiness and transparency evaluations. This study was supported by JSPS KAKENHI 15H05926.

The Interaction of Color and Image Content in Regulating Pupil Size

Joanna Pilarczyk, Kinga Woloszyn and Michał Kuniecki
Institute of Psychology, Jagiellonian University, Poland

Color aids visual perception, facilitating object segmentation and recognition. Color has also emotional connotations. However, the role of color in the perception of emotional images is disputed. We compared pupil dilation in response to images in natural color, in abnormal color, and in grayscale. In the first experiment, we presented only neutral images and their scrambled versions. The effect of color on the pupil size was significant in case of neutral images, while pupil size did not differ between all three color conditions in scrambled images. In the second experiment, we presented emotional images (negative and positive) and neutral ones in natural colors, abnormal colors, and in grayscale. We observed an interaction between color and emotional valence. Moreover, in all cases, the pupil was larger in grayscale condition, despite equal luminance and contrast. Overall, the results show interaction between semantics and physical properties of an image in regulating pupil dilation.

Identifying Surface Colours Across Different Environmental Illuminations

Takuma Morimoto and Hannah Smithson
Department of Experimental Psychology, University of Oxford, UK

Colour constancy supports the estimation of object colour regardless of the lighting environment. However, there have been few direct tests of the identification of glossy objects by their colour. We presented four bumpy computer-rendered objects that were either matte or glossy. Two objects were rendered under one lighting environment and the other two were rendered under a different environment. Objects were presented either with the surrounding environment or in a dark void. Three objects shared the same surface colour, while the forth, target object had a different colour. The observers' task was to identify the target object. Performance improved with the addition of background, but surprisingly specularity had little effect. Since observers' performance improved over sessions, the ability to identify objects by colour is learnable. Finally, it was shown that simulating an observer who identifies surface colours based on mean-chromaticity partially explains observer's performance.

The Effect of Fatigue on Pupil Light Responses

Sergejs Fomins, Alisa Dorofejeva, Gunta Krumina and Renars Trukša
Department of Optometry and Vision Science, University of Latvia, Latvia

The pupillary light reflex (PLR) changes due to fatigue, diameter decrease and fluctuations increase. The study focuses on the fatigue effects in PLR to photopic and melanopsin lights. Nine subjects participated in two experiments to identify the impact of illumination history on the pupillary response during the daytime. In the first experiment, postillumination pupil responses (PIPR) were obtained in the morning and evening sessions to the 2-second impulses. In the second experiment, pupil responses to the sinusoidal light modulation of 0.25 and 0.5 Hz were analyzed. The participants were exposed to the same illumination conditions. The evening recordings showed a pronounced decline in the PIPR in the range of 4 to 8 seconds for red light impulses. The results indicated stronger changes in the pupillary response to red monochromatic light comparing to the morning and evening sessions. The study was supported by the University of Latvia Foundation and SIA "Mikrotîkls" (Project No. 2184).

Computational Models

The Critical Spacing of Crowding With Diffuse Attention

Daniel Coates[1,2] and Bilge Sayim[3]
[1]College of Optometry, University of Houston, TX, USA
[2]CNRS, France
[3]UMR 9193 - SCALab, University of Lille, France

Crowding—the influence of flanking items on identification—is usually studied with a single target at a known location. Here, we compared the critical spacing (CS; extent of flanker interference) in two tasks requiring either diffuse attention to multiple items or focal attention to one item. Rotated *T*s were presented on a ring around fixation with flankers positioned on the foveal and peripheral side of each *T*. In separate blocks, subjects either located an upright *T* (diffuse attention) or identified the orientation of a *T* at a cued position (focal attention). The results showed clear effects of crowding in both tasks, including

characteristic visual field asymmetries. Importantly, the CS with diffuse attention was remarkably similar to the CS with focal attention. Our results indicate that subjects can efficiently extract information from multiple crowded items, revealing parallel pathways with independent bottlenecks of crowding.

Neural Model of the Visual Recognition of Social Intent

Mohammad Hovaidi-Ardestani, Nitin Saini and Martin A. Giese
Department of Cognitive Neurology, Centre for Integrated Neuroscience, University Clinic Tübingen - Hertie Institute for Clinical Brain Research, Germany

Heider and Simmel demonstrated that humans can perceive intent or social interaction from strongly impoverished stimuli. While it has been proposed that this capability requires high-level cognitive processes, such as probabilistic reasoning, we demonstrate that it might be accounted for by rather simple physiologically plausible neural mechanisms. Our model is a hierarchical neural network with two pathways that analyze form and motion features. The highest hierarchy level contains neurons that have learned combinations of relative position-, motion-, and body-axis features. The model reproduces psychophysical results on the dependence of perceived animacy on motion smoothness and body axis direction, and it correctly classifies six categories of social interactions, frequently tested in the psychophysical literature. Simple neural circuits account for a variety of effects in animacy and social interaction perception.

Capsule Networks, but Not Convolutional Networks, Explain Global Configurational Visual Effects

Adrien Doerig, Alban Bornet and Michael H. Herzog
Brain Mind Institute, École Polytechnique Fédérale de Lausanne, Switzerland

In human vision, perception of local features depends on all elements in the visual field and their exact configuration. For example, observers performed a vernier discrimination task. When a surrounding square was added to the vernier, the task became much more difficult: a classic crowding effect. Crucially, adding more flanking squares improved performance (uncrowding). In addition, in displays of squares and stars, small changes in the configuration changed performance strongly. Here, we show that convolutional neural networks fail to address the global aspects of configuration because, first, the target and the flankers' representations at a given layer are pooled within the receptive fields of the subsequent layer, leading to poor performance. Second, far away elements cannot interact with the vernier to produce uncrowding. We show that capsule networks, a new kind of neural network that explicitly takes configuration into account, can capture the experimental results well.

Deep Neural Networks Trained on Ecologically Relevant Categories Better Explain Human IT

Johannes Mehrer[1], Nikolaus Kriegeskorte[2] and Tim Kietzmann[1]
[1]MRC Cognition and Brain Sciences Unit, Cambridge University, UK
[2]Department of Psychology, Columbia University, NY, USA

Deep neural network models (DNNs) reach human-like performance in complex categorization tasks and exhibit representational similarities with the human visual system. Hence, DNNs allow the investigation of the mechanisms underlying cortical selectivity and organization by altering the training setup of the deep networks. Using an ecologically more relevant set of categories, rather than the widely used ImageNet set, may lead to receptive field properties that more closely match the human visual system. We created a new training set consisting of the 565 most concrete and frequent basic-level categories in the English language. Training convolutional DNNs on this ecoset and a similar sized engineering set revealed that the ecologically more relevant visual diet led to significantly improved similarities to response properties in human inferior temporal (IT) cortex. Matching the human and networks' input statistics promises to lead to a better understanding of cortical function.

A Retina Inspired Model for Image Enhancement in Extreme Environments

Xian-Shi Zhang, Yong-Bo Yu, Kaifu Yang and Yongjie Li
School of Life Science and Technology, University of Electronic Science and Technology of China, China

We propose an enhancement model for the single image in extreme environments such as hazy night, dust weather or underwater world. The proposed model is inspired by the visual processing mechanisms in the retina from the layer of photoreceptors to the layer of retinal ganglion cells. The main innovation of this model is to take into account the dynamic gap junction between horizontal cells, which

adaptively adjusts the receptive field size of horizontal cells and indirectly regulates the inhibitory surround sensitivity of bipolar cells. This enables the bipolar cells to maintain local contrast while removing redundant information. Then, the ganglion cells provide a refining and amplifying mechanism for final output. Extensive tests show that our model yields comparative to or even better results than the state-of-the-art methods for simultaneous detail enhancement and haze and dust removal, with much better robustness in different environment.

A Computational Perception Organization Model Based on Tolerance Space Theory

Peng Peng and Yongjie Li
School of Life Science and Technology, University of Electronic Science and Technology of China, China

To understand how human visual system analyzes images, it is essential to know how visual system group discrete elements into individual objects. Tolerance space (TS) theory provides a significant perspective for discrete perception organization. In this work, a computational model based on TS theory is proposed to reconstruct the topological structures from a two-dimensional discrete data set. We first construct an adjacent graph to form an extended TS from data set and then calculate the distance ratio vector and cumulative average ratio vector. A constant threshold used in this model is obtained by a psychophysical experiment, which assists model to form tolerance relation and cut the unnecessary adjacent links in adjacent graph, eventually divide the extended tolerance space to isolated tolerance spaces. This method can also be served as clustering in which the number of clusters arises automatically compared to other clustering methods.

Surround Suppression Explained by Long-Range Recruitment of Local Competition, in a Columnar V1 Model

Hongzhi You[1], Giacomo Indiveri[2] and Dylan Muir[3]
[1]Department of Biomedical Engineering, University of Electronic Science and Technology of China, China
[2]Institute of Neuroinformatics, University/ETH Zurich, Switzerland
[3]aiCTX, AG, Switzerland

Although neurons in columns of visual cortex of adult carnivores and primates share similar orientation tuning preferences, responses of nearby neurons are surprisingly sparse and temporally uncorrelated. Complex visual scenes, and wide-field visual stimulation, drive further decorrelation between neurons and even modify their functional tuning. The mechanisms underlying this counter-intuitive combination of response properties are still unknown. Here, we present a computational model of columnar visual cortex with sparse local excitatory connections and strong local inhibition within columns and functionally specific long-range excitatory connections across columns to reproduce experimental observations. Our results explain surround modulation of responses to simple and complex visual stimuli, including reduced correlation of nearby excitatory neurons, increased excitatory response selectivity, increased inhibitory selectivity, and complex orientation-tuning of surround modulation.

A Computational Model of the Development and Treatment of Anisometropic Amblyopia

Samuel Eckmann[1], Lukas Klimmasch[1], Bertram E. Shi[2] and Jochen Triesch[1]
[1]Computational Neuroscience, Frankfurt Institute for Advanced Studies, Germany
[2]Department of Electronic and Computer Engineering, Hongkong University of Science and Technology, Hongkong

In anisometropia, the refractive powers of the two eyes differ, which can lead to amblyopia. When the refraction error is corrected early in childhood, most patients develop normal vision. In contrast, reduced plasticity in adults is thought to prevent such recovery. Here, we present a computational model of the development of anisometropic amblyopia. The model is formulated in the Active Efficient Coding framework and simultaneously optimizes sensory representations of binocular disparity and vergence control. An interocular suppression mechanism is modeled as neurons with monocular receptive fields attenuating inputs from the other eye. We show that in the healthy case, the model develops normal vision, while in an anisometropic case, an amblyopia-like state emerges. When refraction errors are corrected, the model fully recovers if visual receptive fields are still plastic. In contrast, suppression prevails and amblyopia is maintained for static receptive fields.

Vision-Inspired Automatic Detection of Water Level Changes in Satellite Images: The Example of Lake Mead

Birgitta Dresp-Langley[1], John Mwangi Wandeto[2] and Henry Okola Nyongesa[2]
[1]UMR 7357 ICube, CNRS, France
[2]Computer Vision, Dedan Kimathi University of Technology, Kenya

Time series of satellite images may reveal important changes, undetectable by human vision, in environmental conditions or urban landscape structures. These are of potential interest to citizens, historians, or policymakers. We applied image analysis inspired by biological vision (Self Organized Mapping [SOM]) for detecting critical changes in water levels in satellite images of Lake Mead, Nevada. Statistical trend analysis is applied to show that the quantization error from the SOM output reliably detects both the magnitude and the direction of change across the years of the reference time period in which the satellite images were generated. It is shown that the detector is correlated with relevant demographic data from the same reference time period. The vision-based model is reliable and can be implemented for the rapid detection of potentially critical changes in large time series of images.

A Retina Inspired Color Constancy Model for Scenes With Varying Illumination

Yongjie Li, Yanze Ren, Shaobing Gao and Chaoyi Li
School of Life Science and Technology, University of Electronic Science and Technology of China, China

Computational color constancy for the scenes under varying illumination is quite challenging. Our analysis shows that the bright and dark regions of scenes play quite different roles in coding the local illuminants. Based on this observation, we propose a simple model to estimate the spatially varying illuminant of a color-biased image. Specifically, we first segment the image into two parts, that is, the high and low luminance regions, adaptively according to the luminance dynamic range of the image. Then, we use Difference-of-Gaussian-simulated ON- and OFF-center receptive fields of retinal ganglion cells to infer the local illuminants of the bright and dark areas, respectively. At the last step, the estimated illuminant maps for the bright and dark regions are fused to construct the final illuminant map. Experiments on several synthetic and real multi-illuminant image data sets show that our method obtains quite competitive performance compared to the state-of-the-art algorithms.

Different Use of Visual Information by Humans and Deep Neural Networks

Andrea De Cesarei[1], Giampaolo Cristadoro[2], Shari Cavicchi[1] and Marco Lippi[3]
[1]Department of Psychology, University of Bologna, Italy
[2]Department of Mathematics and Applications, University of Milano-Bicocca, Italy
[3]Department of Sciences and Methods for Engineering, University of Modena and Reggio Emilia, Italy

Visual categorization can rely on different types of visual information (e.g., global or local). deep neural networks (DNNs) are state-of-the-art computational models of vision, which achieve highly accurate visual classification and are used both in basic research and in applied contexts. However, it is not clear whether categorization by DNNs and humans is based on the same visual information. Here, human participants and two DNNs classified natural pictures as animals or vehicles, while the amplitude or phase of the spatial frequency spectrum was degraded. For humans, accuracy and confidence decreased similarly for all types of degradation tested. Categorization by DNNs was linearly dampened by low-pass filtering; for high-pass filtered and phase scrambled scenes, response biases and less linear effects of degradation were observed. This discrepancy suggests that while both DNNs and humans achieve accurate categorization, they seem to rely on different visual information.

Test of Goodness of Population Receptive Field Estimates With Computer Simulations

Arash Ashrafnejad[1], Hossein Mehrzadfar[1] and Huseyin Boyaci[2]
[1]Department of Electrical and Electronics Engineering, Bilkent University, Turkey
[2]Department of Psychology and Neuroscience Program, Bilkent University, Turkey

We present a method based on computer simulations to test the goodness of population receptive field (pRF) estimates. We first simulated functional magnetic resonance imaging (fMRI) responses using linear and nonlinear "simulation HRFs (hemodynamic response function)," and plausible pRFs in the primary visual cortex. We added noise and downsampled the results to obtain fMRI responses per voxel. Next, assuming a certain "estimation HRF," we analyzed the simulated data to estimate the pRFs. Critically, we used different as well as same HRFs for simulation and estimation. We found that a mismatch between the HRFs may lead to erroneous pRF estimations. The errors were particularly severe when the simulation HRF was nonlinear and the estimation HRF was linear.

Because commonly a linear HRF is used to perform pRF estimation, but the actual underlying HRF is likely to be nonlinear, we recommend that the stimulation protocol should be finetuned using computer simulations before an actual fMRI experiment is conducted.

A Mixture of Kalman Filters to Predict Where to Catch a Flying Ball

Marta Russo[1], Benedetta Cesqui[1], Antonella Maselli[2], Francesco Lacquaniti[1] and Andrea d'Avella[3]
[1]Department of Systems Medicine and Center of Space Biomedicine, University of Rome Tor Vergata, Italy
[2]Laboratory of Neuromotor Physiology, Santa Lucia Foundation, Italy
[3]Department of Biomedical and Dental Sciences, University of Messina and Santa Lucia Foundation, Italy

Catching a flying ball involves an internal estimate of gravity to accurately predict where the interception will occur. Indeed, we recently reported that spatial errors are larger when intercepting non-accelerated than accelerated approaching virtual balls. However, performance differences decrease with flight duration. To explain these observations and to better understand how prior knowledge of gravity is combined with sensory information, we modelled the prediction process with a mixture of two Kalman filters. One filter assumes a motion accelerated by gravity and the other a constant velocity motion. Kalman filtering allows each expert to integrate prior and sensory input, while a gating network is responsible for selecting and mixing the predictions made by the two experts. The final optimal estimate is compatible with the experimental results, indicating, as an existence proof, that a hybrid controller could underlie the control of interceptive actions.

Multimodal Neuroimaging of Interocular Contrast Responses in Human Amblyopia

Freya Lygo[1], Bruno Richard[2] and Daniel Baker[1]
[1]Department of Psychology, University of York, UK
[2]Department of Mathematics and Computer Science, Rutgers University, NJ, USA

In amblyopia, neural responses from the amblyopic eye are attenuated compared to fellow eye responses. Interestingly, attenuation is greater when measured with steady-state visual-evoked potentials (SSVEPs) than functional magnetic resonance imaging (fMRI) measurements. We directly compared these two techniques by measuring interocular responses of amblyopic participants ($N = 12$) and controls ($N = 10$) to sinusoidal gratings (4 Hz flicker) of different contrasts (0%, 1.5%, 6%, 24%, and 96%), factorially combined across the two eyes. We found a deficit in the amblyopic eye response, which differed between SSVEPs and fMRI in a manner similar to previous reports. We explored different computational models of binocular vision in amblyopia to explain these responses. An attenuation model provides adequate fits for both data sets, but a shift in contrast gain improves model fits for SSVEP data. This suggests subtle architectural differences for data derived from different modalities.

Contrast Invariance in Deep Neural Networks

Arash Akbarinia and Karl Gegenfurtner
Psychologie und Sportwissenschaften, Justus-Liebig Universität, Germany

While human vision is invariant to contrast, this holds, to certain degrees, for deep neural networks (DNNs). We explored the underlying mechanisms in DNNs by measuring activation of kernels exposed to identical images of different contrasts. We retrieved the most activated kernels for different level of contrasts. Then, we computed the portion of kernels at every layer that remained most activated across different contrast levels. This is an indicator of contrast variation for a layer. In DNNs with more than one convolutional layer before the first max pooling (VGG and Inception), the last convolutional layer before the first max pooling shows more contrast variance by a large margin. Others with a max pooling right after the first convolutional layer (GoogLeNet and AlexNet) do not show this pattern while also performing worse in changes of contrast. It seems that contrast variance emerges through multiple convolutional layers before a max pooling, resembling the concept of a cortical area with multiple layers.

Temporal Distribution of Saccades With Deep Learning Salience Maps

Sofia Krasovskaya[1], Georgii Zhulikov[2], Liya Merzon[1] and Joseph MacInnes[1]
[1]Department of Psychology, National Research University Higher School of Economics, Russia
[2]Department of Computer Science, National Research University Higher School of Economics, Russia

The classic Saliency Model by Itti and Koch launched many studies that contributed to the modelling of layers for vision and visual attention. The aim of this study is to improve the existing saliency model by using a neural network to generate salience maps to model human saccade

generation. The proposed model uses a Leaky Integrate-and-Fire layer for temporal predictions and replaces spatial salience with a deep learning neural network in order to create a generative model that combines spatial and temporal predictions. The results involve a deep neural network, which is able to predict eye movements based on unsupervised learning from raw image input as well as supervised learning from fixation maps retrieved during an eye-tracking experiment with 35 participants at later stages in order to train a two-dimensional softmax layer. The results imply that it is possible to match model human fixation locations, but temporal distributions are still limited by the accuracy of the leaky algorithm.

The Neural Codes Underlying the Distortion of Relative Frequency

Xiangjuan Ren[1], Huan Luo[2] and Hang Zhang[2]
[1]Peking-Tsinghua Center for Life Sciences, China
[2]Academy for Advanced Interdisciplinary Studies, Peking University, China

In judgment and decision-making, humans distort probability or relative frequency in a systematic way: small probability overestimated and large probability underestimated. How does the distortion arise in the brain? Here, we investigated a visual relative frequency judgment task and used electroencephalography (EEG) to reveal the neural coding of relative frequency. In the first experiment (25 subjects) with a steady-state response design, we found phase-locked neural responses to visual relative frequency and numerosity (the total number of dots in a display). In a second experiment (17 subjects), we combined the temporal response function method with model comparison to test among possible codes of relative frequency and numerosity. Through stimulus reconstruction from EEG signals, we identified multiple time windows that imply different coding schemes.

Deep Convolutional Neural Networks Discriminate Between Different Types of Material Kinematics

Hossein Mehrzadfar[1], Alexandra Schmid[2], Arash Ashrafnejad[3], Huseyin Boyaci[4] and Katja Doerschner[2,5]
[1]Graduate School of Engineering and Science, Neuroscience Program, Bilkent University, Turkey
[2]Department of Psychology, Justus-Liebig-University Giessen, Germany
[3]Department of Electrical and Electronics Engineering, Bilkent University, Turkey
[4]Department of Psychology and Neuroscience Program, Bilkent University, Turkey
[5]Department of Psychology, Bilkent University, Turkey

Humans are very good at estimating the material qualities of objects by extracting information from two-dimensional (2D) images. However, it has also been shown that image motion provides a powerful source of information for recognizing material properties, often beyond what is available in static scenes. Even when surface information is absent, as in sparse point light displays of moving materials, humans easily make judgments about various material qualities. Here, we used a dense version of such point light displays to test whether adding a time dimension to deep convolutional neural networks (DCNNs) substantially improves recognition of dynamic materials. Specifically, we contrasted recognition performance of 2D and three-dimensional (3D) DCNNs that were trained on eight material categories (144 samples per category). We found that, while the 2D DCNN (87.3% recognition) is outperformed by the 3D version (97.8% recognition), it may be able to "use" the spatial features for recognition more efficiently than human observers do.

Capturing Attentional Capture With Salience Models

Joseph MacInnes[1], Lena Gorina[1], Alexey Asvarisch[1], Anastasia Comardin[1] and Tatiana Malevich[2]
[1]School of Psychology, National Research University Higher School of Economics, Russia
[2]Department of Neurophysiology, Reichardt Centre for Integrative Neuroscience, Germany

Salience models have launched decades of research into models of vision and the allocation of overt attention. They represent the various layers of visual processing and predict fixations by analysing low-level image properties. Some models generate temporal predictions, which can be compared to human saccade distributions in search. Rather than static images, we modify the salience model for attentional capture. Our model accepts changing

spatial input and responds using the standard Leaky Integrate and Fire (LIF) layer. Input to the model was from the classic Posner's cuing paradigm, and response times were compared to human data. The model was able to partially simulate facilitation but not inhibition of return (IOR). This pattern of results remained after optimising the LIF parameters using a genetic algorithm. Finally, we replaced the LIF with a drift-diffusion process. This improved the temporal distribution but could reproduce IOR with separate parameters.

Eye Movements as Predictors of Visual Detection

Paola Suárez[1], Martin Rolfs[1] and Alex L. White[2]
[1]Department of Psychology, Bernstein Center for Computational Neuroscience, Humboldt-Univeristät zu Berlin, Germany
[2]Department of Psychology, University of Washington, WA, USA

Microsaccades are briefly inhibited when we detect a visual stimulus. Indeed, their occurrence can be used to predict visual detection on a single trial. As microsaccades are rare events, we assessed whether other features of fixational eye movements or pupil size provide additional information about an observer's report of stimulus detection. We applied classification algorithms to a range of features of eye movements recorded in a visual detection task. We compared three well-known algorithms used in binary classification: Support Vector Machines, Random Forest Ensemble, and Linear Discriminant Analysis. For stimuli at contrast detection threshold (where presence/absence reports are most balanced), classification performance of each classifier was ~70%. While this performance level is similar to the Bayesian classifier reported for microsaccades only, different sets of features were important in each classifier. Thus, eye movements can be used to predict subjective perception.

What Are the Sparse Components of 2D Shapes?

Michaël Clément and James H. Elder
Centre for Vision Research, York University, Canada

The receptive fields of neurons in the early visual cortex have been found to resemble the sparse components of natural image patches, suggesting a major role for sparse coding in the functional organization of the visual system. However, this result has not yet been extended to higher levels of visual perception. In this work, we study the sparse components of two-dimensional (2D) planar shapes, represented numerically by low-dimensional polygons. We employ a data set of 45,000 blue-screened shapes to learn an optimal sparse linear basis for 2D shapes under L1 (LASSO) regularization. Leading sparse components are low-pass and exhibit high degrees of rotational and bilateral symmetry. We compare these sparse components to what is known of shape selectivity in areas V4 and posterior IT of primate visual cortex.

Crowding

Visual References Reverse Diminishment in Crowding

F. Zeynep Yildirim[1], Daniel Coates[2] and Bilge Sayim[3,4]
[1]Institute of Psychology, University of Bern, Switzerland
[2]College of Optometry, University of Houston, TX, USA
[3]Institute of Psychology, University of Bern, Switzerland
[4]SCALab – Sciences Cognitives et Sciences Affectives, University of Lille, France

We recently showed that crowding, the deleterious influence of flankers on target perception, diminishes the number of perceived items. When three items are presented, observers frequently report only two. Here, we investigated the malleability of this effect. Participants were briefly presented with one to five items in the periphery, indicating the number of items. When the items varied in shape and arrangement within blocks (Experiment 1), the estimation of three lines was—as expected—significantly reduced (average response = 2.3 lines). However, when each block comprised arrays of equally spaced lines (Experiment 2), the diminishment effect reversed (average = 3.4 lines). The outcome of Experiment 2 was likely due to automatic, compulsory comparisons between trials. Stimulus heterogeneity precluded such comparisons in Experiment 1, resulting in a more accurate estimation of unbiased perception. Similar referential effects may inadvertently enhance the performance and obscure crucial aspects of appearance in many crowding paradigms.

Development of Contour Interaction and Crowding With Age

Sarah Lalor, Monika Formankiewicz and Sarah Waugh
Vision and Hearing Sciences Department, Anglia Ruskin University, UK

The presence of 'crowding' features on visual acuity tests for young children is important for detecting amblyopia, early treatment of which is key to success. Previous research has shown that contour interaction and crowding are increased if flankers are placed closer than on commercially available charts. Contour interaction effects are

most consistent across test if flanker placement is specified edge-to-edge in stroke widths. Adult ($n = 10$) and 3- to 16-year-old ($n = 90$) participants had acuities measured for individual optotypes isolated and surrounded by a box placed one stroke width (edge-to-edge) away from Kay Picture, Lea Symbol and HOTV optotypes. Additionally, HOTV optotypes were surrounded by letters. New findings show a similar magnitude of contour interaction ($\sim$0.1 logMAR) across age. The magnitude of crowding for letters reduces with age (from $\sim$0.4 to $\sim$0.15 logMAR). Contour interaction and crowding must be limited by different underlying factors.

Perceptual Learning and Visual Crowding: Results of Multivariate Pattern Analysis of Functional MRI

Maja Traurig, Tina Plank, Maka Malania and Mark Greenlee
Institute for Experimental Psychology, University of Regensburg, Germany

Visual crowding is the inability to recognize objects in clutter when viewing them with peripheral vision. Visual perceptual learning (VPL) can reduce crowding effects. Eleven subjects viewed radially and tangentially target (Landolt C) and flanker (same-sized circles) arrangements during functional magnetic resonance imaging (fMRI) before and after 4 days of training on a gap detection task. Stimuli were presented in the right upper quadrant 6.5° eccentric from central fixation. Support vector machines were applied to the fMRI data acquired in retinotopically defined and anatomical regions of interest (ROIs) in visual cortex. Classification accuracy increased for radial compared to tangential target-flanker arrangements after VPL in the functional ROI ($p = .02$), in V1, V3, lateral occipital, and inferotemporal cortex. A comparison between fMRI classification rates and changes in psychophysical performance suggests that VPL enhances response selectivity in early and higher level visual cortex, thereby improving gap detection during crowding.

Using Visual Crowding as a Tool to Study Feature Binding

Niloufar Razmi
Department of Medicine, Mashhad University of Medical Sciences, Iran

It has recently been proposed that accuracy of detecting a visual stimulus under unconscious visual perception diminishes as the stimulus becomes more complicated. To study different stages of feature integration, we designed a crowding experiment where discrimination of a single feature versus conjunction of two features was compared. A set of three stimuli was shown in eccentricity to produce crowding effect, and subjects were asked yes/no question about the features of the middle target. Different combinations of features were examined under different conditions of eccentricity. It was observed that in some conditions, while subjects were able to report all the individual features in separate sessions, they still could not bind the features together in one session. We also compared their accuracy of binding two features based on which features were combined. We propose that we can use visual crowding as a tool to study the dynamics of feature binding.

Radial-Tangential Anisotropy of Visual Crowding Can Be Modulated by Training

Maka Malania, Tina Plank and Mark Greenlee
Institute for Experimental Psychology, University of Regensburg, Germany

One of the hallmarks of visual crowding, the radial-tangential anisotropy, has been observed both in behavior experiments and in responses of functional magnetic resonance imaging (fMRI) blood oxygenation level-dependent (BOLD) signal. We examined the effect of training on the neural correlates of crowding. It has been shown crowding is stronger for radially arranged flankers that is reflected in BOLD signal reduction. We expected that training on crowding task will cause alteration of crowding area that will be mirrored in corresponding BOLD signal responses. Pre- and posttraining fMRI images were acquired in 10 healthy volunteers using 3-Tesla MRI scanner. Participants were trained over several days. Prior to training, all participants showed suppressed BOLD signal in the condition with target-plus-radial flankers. After training, we found increase in BOLD signal on target-plus-radial condition compared to target absent condition. Our results suggest that neural correlates of visual crowding can be modulated by training.

Target-Flanker Dissimilarity Alleviates Clutter-Induced Cortical Interference of Targets in Crowded Scenes

Leili Soo, Ramakrishna Chakravarthi and Søren K. Andersen
School of Psychology, University of Aberdeen, UK

Cortical processes leading to crowding, an impairment of object recognition in clutter, are still debated. Previous findings in our laboratory showed that accuracy and concurrently recorded steady-state visual-evoked potentials

(SSVEPs) decline as target-flanker distance reduces, suggesting that SSVEPs can assess the cortical processes underlying crowding. Here, we varied target-flanker similarity, a manipulation known to modulate the spatial extent of interference from flankers, in an orientation discrimination task of frequency-tagged targets presented in isolation or surrounded by flankers at varying distances. As before, identification accuracy and target-elicited SSVEP amplitudes decline as flanker distance decreases. However, this decline is alleviated for targets surrounded by dissimilar flankers. This alleviation suggests that competition between stimuli for processing resources in the visual cortex is closely related to the behavioural phenomenon of crowding.

Decision-Making

Low-Level Image Statistics in Natural Scenes Influence Perceptual Decision-Making

Noor Seijdel[1], Sara Jahfari[1], Iris I. A. Groen[2] and H. Steven Scholte[1]
[1]Department of Psychology, University of Amsterdam, the Netherlands
[2]Department of Psychology, New York University, NY, USA

A fundamental component of interacting with our environment is the gathering and interpretation of sensory information. Unlike simplified, artificial stimuli, real-world scenes contain low-level regularities that are informative about the structural complexity. Here, participants performed an animal detection task on low, medium, or high complexity scenes as determined by two biologically plausible natural scene statistics, contrast energy (CE), or spatial coherence (SC). In Experiment 1, both CE and SC indexed scene complexity. Diffusion modeling showed an influence on both the speed of information processing and the required evidence. Experiment 2a and b refined these results by showing how manipulating SC alone had comparable effects, whereas manipulating only CE did not. Overall, performance was best for scenes with intermediate complexity. We speculate that the computation of CE and SC serves as an indication to adjust perceptual decision-making based on the complexity of the input.

Investigation of Video-Conference Communication in an Evaluation Interview

Susumu Shibui
Research Department, National Institution for Academic Degrees and Quality Enhancement of Higher Education, Japan

Technological progress has facilitated the increase in the use of videoconferencing in recent years. To ensure effective videoconferencing, it is necessary to clarify the differences between face-to-face communication and that using videoconferencing. This study examines the effects of videoconferencing in university evaluation interviews in Japan. Interviews were conducted by 36 university executives and 113 evaluators via videoconferencing and were then assessed for the appropriateness of communication on a 5-point scale. In addition, free descriptions about the merits and demerits of communication were analyzed using text mining. Evaluators compared with university evaluators, on average, felt that communication was more appropriate, $t(147) = 2.29$, $p < .05$, $r = .19$. The analysis of free descriptions highlighted the terms "reality," "face size," and "voice loudness." These results gave some insight into the appropriate usage of videoconferencing.

The Effect of Perceptual Semantic Blindness in Making Cognitive Decisions

Sergei Artemenkov
IT, Moscow State University of Psychology and Education, Russia

The effect of perceptual semantic blindness shows the natural absence of the inclusion of the process component of visual perception in the conscious cognitive process of solving semantic problems, guided by attention, using thinking. When solving semantic tasks, the perception process is given a subordinate role of the rapid translation of situational stimuli into the knowledge base with which thinking works, referring only to the functions of semantic memory. As a result, the possibility of making decisions by finding practically obvious answers that are present in the common field of view is lost. The conducted experiments showed that the effect of perceptual semantic blindness is observed in the actions of the subjects solving the semantic problems associated with situational perception in the overwhelming majority of cases. One might think that this can be considered one of the results of the sociocultural development of the intellect in the conditions of modern society.

Confidence as a Priority Signal in Perceptual Decision-Making

David Aguilar-Lleyda, Maxime Lemarchand and Vincent de Gardelle
Centre dÉconomie de la Sorbonne, CNRS & Paris 1, France

Perceptual decisions are often followed by a sense of confidence, the subjective certainty in the correctness of our choices. An ongoing debate is whether confidence has an active role shaping our future behavior. In situations involving multiple tasks, such a role could be acting as a priority signal that determines the order in which we deal with each task. We tested this hypothesis by presenting an array of O or X, colored blue, or orange. Participants had to report both which letter and color were more frequent in each trial, in the order they chose. The difficulty of one task relative to the other was varied across trials. When a task's difficulty was reduced, we found an increased probability of that task being responded to first, irrespective of any particular bias participants could have toward either task. Easier tasks were also related to higher self-reported confidence. Our results support the role of confidence as a priority signal.

Dynamics of Prior Expectation on Human Perceptual Decision-Making

Nuttida Rungratsameetaweeman[1], Sirawaj Itthipuripat[2] and John Serences[1]
[1]Neurosciences Graduate Program, University of California, San Diego, CA, USA
[2]Department of Psychology, Vanderbilt University, TN, USA

Expectations about likely features or motor responses play an important role in shaping behavior. While classic accounts posit that expectation biases late 'post-perceptual' stages of decision-making, recent accounts hold that expectation modulates early sensory processing. In Experiment 1, we isolate the effects of expectation from attention and examine how expectation impacts a set of electroencephalography markers that index early sensory processing and later post-perceptual processing. We show that while expectation has no impact on early sensory processing, violating expectations impacts time-on-task and cognitive conflict. In Experiment 2, we examine the temporal dynamics of expectation and attention on a continuous decision task and show that attention affects early sensory processing, whereas expectation modulates late stages of decision-making. These findings suggest that expectations primarily influence decisions by modulating response selection and cognitive control processes.

Behavioral and Neural Effects of Feedback Manipulation on Perceptual Inference

Rekha Varrier, Heiner Stuke, Matthias Guggenmos and Philipp Sterzer
Klinik für Psychiatrie und Psychotherapie, Charité Universitätsmedizin Berlin, Germany

According to Bayesian theories, unreliable feedback compromises inference by decreasing the precision of likelihood distributions and shifting inference toward prior expectations. Here, we investigated these hypotheses in two behavioral and one fMRI experiment. In separate sessions, participants received either correct or manipulated feedback while performing visual tasks (detection/discrimination). Behavioral experiments additionally included pretrained probabilistic cues serving as prior information. Behaviorally, we found predicted effects of impaired performance and increased reliance on prior information for manipulated relative to correct feedback. In addition, using multivariate pattern analysis, we delineated neural representational changes in early visual cortex underlying these behavioral effects. Our results suggest that manipulating feedback in a perceptual task affects the precision of likelihood representations and biases perceptual inference toward prior information.

Detection of Evidence Reliability Changes in Random-Dot Motion

Emmanouil D. Protonotarios, Lingyu Gan and Michael S. Landy
Department of Psychology and Center for Neural Science, New York University, NY, USA

To make sensory decisions quickly and accurately, it is useful to know whether stimulus information is improving or not to decide when to stop and respond. To explore this, we measured the ability to discriminate increasing from decreasing coherence in a random-dot kinematogram. Coherence ramped up or down at constant rate for 2 seconds centered on one of the four mean coherence levels. Interleaved staircases controlled the rate of coherence change. We first determined coherence threshold for direction discrimination (the just noticeable difference (JND)). For the ramps, we fit a cumulative normal to probability of saying "upward" as a function of actual rate. Threshold for coherence change discrimination was \sigma $= 2.2 \pm 0.23$ JND/s for the three highest mean-coherence conditions. There was also a significant bias: highest for the lowest mean coherence and decreasing with increasing mean coherence. Therefore, observers can perceive stimulus changes at time scales and stimulus levels comparable to those of the decision process.

How Dynamic Visual Cues Help to Expose a Liar: Laban/Bartenieff Movement Studies in the Field of Police Interviewing

Sandra Adiarte
Department of Human Sciences, Otto-Friedrich-University, Bamberg, Germany

The body and its movement represents an intelligent and highly dynamic system, which has a great impact on interaction due to embodied cognition. This fact influences the evaluation of behavior tremendously. In the present study, we employed Laban/Bartenieff Movement Studies to observe police interviews. Within the context of an observational double-blinded and randomized expert analysis, we evaluated 34 standardized video-based police interviews in relation to a bogus theft. The data were compared at three defined time frames (baseline, free report, and first accusation). Results are promising to develop categories to offer a comprehensive catalogue of dynamic visual cues for effective lie detection.

Development

Development of Allocentric Spatial Representation in Visually Impaired Children

Chiara Martolini[1], Giulia Cappagli[2], Sabrina Signorini[3], Antonella Luparia[3], Eleonora Perrotto[3] and Monica Gori[1]
[1]Unit for Visually Impaired People, University of Genoa, Italy
[2]Unit for Visually Impaired People, Italian Institute of Technology, Italy
[3]Unità operativa Neurologia dell'Infanzia e dell'Adolescenza, Fondazione Istituto Neurologico Casimiro Mondino, Italy

While the development of allocentric perspective-taking has been widely studied in the sighted, reporting some primitive forms of viewer-independent representations during early infancy, less is known about how blind children are able to switch from an egocentric to an allocentric frame of reference across childhood. Our study assessed the ability of 4- to 10-year-old children with and without visual disability to switch from an egocentric to an allocentric perspective. Children replicated a visual configuration of three colored tokens differently positioned on a board by a therapist, either assuming the therapist's perspective or rotating by 90° or 180° respect to the therapist's position. Our results showed that visually deprived children are impaired in assuming the therapist's perspective in rotating conditions independently of the age. This suggests that switching from an egocentric to an allocentric perspective is generally delayed when vision is degraded from an early age.

The Time-Based Expectancy in Children and Young Adolescents

Marina Kunchulia[1], Khatuna Parkosadze[1] and Roland Thomaschke[2]
[1]Institute of Cognitive Neurosciences, Agricultural University of Georgia, Georgia
[2]Time, Interaction, and Self-determination Group, at the Cognition, Action and Sustainability Unit, Department of Psychology, University of Freiburg, Germany

Recently, we reported that the ability to form time-based event expectancies was not fully developed in school-aged children. Here, we investigated the relationship between the development of time-based expectancy and cognitive abilities, specifically interference suppression, short-term memory, and working memory, in children and young adolescents. Sixteen children aged 6 to 10 years and 16 young adolescents aged 11 to 14 years completed a binary choice response task in which foreperiod duration predicted the response target with a probability of .9. In addition, a bivalent shape task measuring interference suppression, a forward digit test measuring short-term memory, and a backward digit test measuring working memory were administered. We found that young adolescents, in contrast to children, were able to form time-based event expectancies. However, the ability to form time-based expectancies was not correlated with performance in other cognitive tests.

Phantom Stereopsis in 5- and 7-Month-Old Infants

Michael Kavšek
Department of Psychology, University of Bonn, Germany

This natural preference study investigated infants aged 5 and 7 months for their ability to perceive phantom contours, illusory surfaces generated by half-occlusions embedded in a stereogram depicting two parallel vertical lines. Infants in the main condition were presented with a standard phantom stereogram displaying a coherent illusory contour moving up and down in front of the two lines versus a non-standard phantom stereogram, that is, the same stimulus with inversed half images. The non-standard phantom stereogram evokes the impression of two small separate illusory contours moving up and down above the lines. The participants aged 7 months but not 5 months looked significantly longer at the standard phantom stereogram. A control condition supported the hypothesis that the older infants in the main condition indeed responded to the phantom contour as a coherent whole. The results indicate that infants are able to extract spatial information from monocular regions in a binocular display.

Comparison of a Tablet Based and Chart Projector Visual Acuity Tests

Eszter Mikó-Baráth[1], Anna Budai[1], David Pinero[2], Janka Juszt[1], Vanda Nemes[1], András Czigler[1] and Gábor Jandó[1]
[1]Department of Physiology, University of Pécs, Medical School, Hungary
[2]Department of Optics, Pharmacology and Anatomy, University of Alicante, Spain

Visual acuity (VA) testing is a basic ophthalmological tool used by doctors and medical professionals. The conventional measurements of VA have several shortcomings resulting in low test–retest reliability especially in children, making the early screening more difficult. Our laboratory is developing a complex tablet-based amblyopia screening software (EuvisionTab), including a VA-application using Best-PEST algorithm, with a variety of settings. We compared the monocular best corrected VA (BCVA) results of children (n = 185; 4–10 years) measured both with EuvisionTab and chart projector. As our application has a much higher measurement range, we found far better monocular VAs in the emmetropic group (1.67 od–1.64 os) than measured by the chart projector (0.997 ou). Comparing the interocular BCVA differences in the group of amblyopic children, higher difference (t test, p .05) was found using EuvisionTab than using chart projector. That may make the diagnosis of the condition univocal.

Chromatic Preference of Art Paintings by 6- to 12-Year-Old Children

Tomoko Imura[1], Taisei Kondo[2], Nobu Shirai[3] and Shigeki Nakauchi[2]
[1]Department of Psychology, Japan Women's University, Japan
[2]Department of Computer Science and Engineering, Toyohashi University of Technology, Japan
[3]Department of Psychology, Faculty of Humanities, Niigata University Japan

Recent studies have shown that adults prefer a chromatic composition very close to the original when asked to rotate the color gamut of paintings. Although there is inconsistent evidence for the color preferences of infants and children, little is known about the development of color preferences for art paintings. We measured children's preferences for the chromatic composition of art paintings using the four-alternative forced choice paradigm. Seventy-three children (aged 6–12 years, 34 males) participated in the current study and selected which of four images of paintings they most preferred: original (0°) and three hue-rotated images (90°, 180°, and 270°); the luminance and mean chromaticity of all images were the same as those of the original. Twenty-four paintings in three categories (abstract, poster, and flower) were used as visual stimuli. Results showed that children preferred the original images, regardless of the category, and that preference for the original images increased with age.

Perceptual Development From "Pre-Constancy" to "Constancy" in Infants

So Kanazawa[1] and Masami K. Yamaguchi[2]
[1]Department of Psychology, Japan Women's University, Japan
[2]Department of Psychology, Chuo University, Japan

Based on our previous studies, we propose a new hypothesis that 5 months to 7 months after birth is an important stage for the development of infants' general perception. Yang et al. showed a decisive difference in the perception of infants aged 3 and 7 months. Specifically, they showed that 3-month-old infants have a striking ability to discriminate slight image changes due to illumination that are not salient for adults, and that they lose it with development, by the age of 7 months. This distinction was based on the difference between infants with and without "constancy." According to our hypothesis, 7-month-old infants with "constancy" can perceive objects despite changes in the lighting and viewpoint, whereas 3-month-olds without it perceive the retinal image directly. We call this perception without constancy as "pre-constancy." We discuss the relationship between "pre-constancy" and "blooming, buzzing confusion".

The Role of Horizontal, Vertical, and Sagittal Axes on Visuo-Spatial Number Mapping in Children

Sarah Cooney, Corinne Holmes and Fiona Newell
School of Psychology and Institute of Neuroscience, Trinity College Dublin, Ireland

Previous research has consistently found evidence for differential effects of axis direction on object and spatial perception. We asked if this anisotropy is also evident for visuo-spatial number mapping by testing whether horizontal number–space mapping (i.e., when small/large numbers are responded to faster on the left/right side of space; spatial-numerical association of response codes effect) generalizes to other axes. We also investigated how spatial numerical associations on these axes develop in childhood. Based on a two-alternative forced choice paradigm, both children (aged 5–10 years) and adults participants performed a single-digit magnitude comparison task with response buttons positioned up/down (vertical), left/right (horizontal), and near/far (sagittal). Our results suggest visuo-spatial number mapping exists on all three axes, but that these associations are not modulated by

development across axes. Our results have important implications for the role of perceptual development on both spatial and numerical cognition.

Studying the Development of Visual Attention With Foraging Tasks

Inga María Ólafsdóttir, Steinunn Gestsdóttir, Tómas Kristjánsson, Ómar I. Jóhannesson and Árni Kristjánsson
Department of Psychology, University of Iceland, Iceland

Visual foraging, where participants select multiple targets among distractors, is a dynamic way to study visual attention. To gain insight into how foraging abilities develop, the performance of children was measured in two studies. In Study 1, the foraging of 4- to 7-year-olds was compared with adult foraging patterns. In Study 2, 11-year-olds were tested. Foraging ability improves dramatically between the ages of 4 and 11 years, evident by different foraging patterns, faster foraging, and greater ease of switching between target types. The older children's performance closely resembles that of adults, whereas the younger children are slower and more erratic. Curiously, although the youngest participants were slow and prone to error, the foraging patterns of 4-year-olds are closer to adult performance than those of 6- to 7-year-olds, which may reflect the 6- to 7-year olds failed attempt at strategizing. Foraging is a promising way to study the development of visual attention throughout the life span.

Functional and Structural Plasticity in Hydrocephaly

Michael Crognale, Shuiting Cheng, Zhiheng Zhou and Lars Strother
Department of Psychology, University of Nevada, Reno, Nevada

Hydrocephaly commonly results from restricted circulation of cerebral spinal fluid (CSF) during early development. It is marked by accumulation of CSF in the brain with enlarged ventricles and increased pressure on the developing tissue, resulting in significant decrease in cortical volume. Despite gross anatomical abnormality, successful early shunting halts progression and often allows for impressive recovery of function. However, little is known about how reorganization of connections and function provide this tribute to neural plasticity. We characterized anatomy, function, and connectivity in a hydrocephalic participant with a condition that is largely unilateral and occipital. Despite large anatomical abnormalities and loss of tissue, visual function appears unaffected. Functional imaging reveals a remapping of visual space and sharing across hemispheres. Diffusion tensor imaging reveals abnormal cortical projections and rerouting of inter- and intrahemispheric connections. This study was supported by NIH P20 GM103650.

Reaching to the Body in Blind Children

Giulia Cappagli[1], Monica Gori[1], L. K. Chinn[2], J. J. Lockman[2], M. Hoffmann[3], Elena Cocchi[4] and Sabrina Signorini[5]
[1]Unit for Visually Impaired People, Istituto Italiano di Tecnologia, Italy
[2]Department of Psychology, Tulane University, LA, USA
[3]Department of Cybernetics, Faculty of Electrical Engineering, Czech Technical University in Prague, Czech Republic
[4]Istituto Chiossone Onlus, Italy
[5]Fondazione Mondino, Italy

Several studies suggest that congenitally blind individuals represent their bodies and the space around them differently, with motor-based or skin-based coding of stimuli being relatively more prominent than the use of external reference frames (visually mediated in sighted individuals)—as demonstrated in the temporal order judgment task for crossed limbs, for example. In this study, we employ a different paradigm, whereby subjects are stimulated with a vibrating stimulus attached to different parts of their bodies. We compare the responses of blind, visually impaired, and normal children of different ages (1–6 years), looking in particular at the ability to reach to the buzzers at different locations and the strategies to reach for them. These include the action of both the "reaching limb" and the body part where the buzzer is placed, their trajectories and timing, and the percentage of employing ipsilateral versus contralateral limb.

Development of Contrast Sensitivity in Children: Using a Novel Child-Friendly Method

Mahtab Farahbakhsh, Pete R. Jones and Tessa Dekker
Institute of Ophthalmology, University College London, UK

While the development of contrast sensitivity in children has been studied before, there still exists disagreements on the time course and the nature of this development. This may be due to lack of a robust, quick, and child-friendly measure of the contrast sensitivity function. We implemented a novel measure of contrast sensitivity in children using an adaptive Bayesian method, QUEST+. Using this method, we measured contrast sensitivity of 46 children (4- to 14-year-old; 8.90 $\pm$ 2.18) and 43 adults (21.78 $\pm$ 2.69). Our analyses reveal that contrast sensitivity increases with age. A detailed comparison across age

suggests that in particular, contrast sensitivity of adults is significantly higher than children in spatial frequencies lower than 5 cpd. This has important implications in clinical vision science by adding information over the current clinical gold-standard, visual acuity measures. In addition, our data provide a baseline measure of contrast sensitivity function for children.

Emotion Specificity of the Inversion Effect in Younger and Older Adults

David Kurbel[1], Bozana Meinhardt-Injac[2], Malte Persike[1] and Günter Meinhardt[1]
[1]Department for Statistical Methods, Johannes Gutenberg University Mainz, Germany
[2]Department for Developmental Psychology, Johannes Gutenberg University Mainz, Germany

Recognition of emotional facial expressions improves until young adulthood (YA), while there is a notable decline in older adults (OAs). Some emotions are more affected by aging than others. The present study spots these differences between YA and OA. Seventy-three subjects participated in an emotion recognition test based on the Radboud Faces Database with upright and inverted faces. With upright faces, OAs performance was worse only for surprise and sadness. Inversion impaired emotion recognition notably for the elderly, particularly for anger, disgust, fear, and sadness which require the combination of different facial cues. However, analyzing the confusion matrices revealed highly similar confusion errors for both upright and inverted faces as well as younger and older adults. These results speak for similar processes in YA and OA, indicating quantitative decline in the efficiency of reading facial cues rather than qualitative changes in OA, as their overall weaker performance shows.

Dark-Reared Rats Develop Higher Visual Acuity Than Controls in an Orientation Discrimination Task

Natalia Grion, Ilaria Montano, Giulio Mateucci and Davide Zoccolan
Cognitive Neuroscience, SISSA, Italy

Visual experience plays a key role in shaping the neural circuitry during the critical period. Since this phenomenon has been studied mainly at the neurobiological/electrophysiological level, we aimed to characterize the visual system capability in dark-reared rats with a battery of psychophysical tests. After 125 days from birth in the dark (DR), animals were tested for visual spatial frequency (SF), orientation and contrast acuity in a two-alternative choice task with gratings as stimuli. DRs showed (a) higher SF acuity, (b) better orientation at higher SFs, and (c) higher contrast acuity tendency than control group. This means that rats had a full visual recovery with gain in acuity. We hypothesize that the visual cortex would be in a newborn-like state at the completion of the dark period, which could have facilitated the optimization for the gratings statistical properties. Overall, these findings set the basis for new studies on visual development and functional models of sensory processing.

Eye Movements

Eye Tracker Calibration in Individuals With Highly Unstable Gaze Due to Involuntary Nystagmus

Paul Zerr[1], Ramesh Kekunnaya[2], Idris Shareef[2], Kabilan Pitchaimuthu[1], Stefan Van der Stigchel[3], Brigitte Röder[1] and José Ossandon[1]
[1]Department of Biological Psychology and Neuropsychology, Hamburg University, Germany
[2]Jasti V Ramanamma Children's Eye Care Centre, L V Prasad Eye Institute, India
[3]Helmholtz Institute, Experimental Psychology, Utrecht University, the Netherlands

Clinical nystagmus is typically characterized by involuntary, fast, periodic eye movements. Following drift, corrective saccades repeatedly return the eyes to a point of fixation. Highly unstable gaze is a challenge for eye tracker calibration and gaze monitoring. Unsurprisingly, very few studies have investigated, for example, image viewing in individuals with involuntary nystagmus. Here, we present a procedure and convenient interface for calibrating an eye tracker in individuals with highly unstable gaze patterns. Informed selection of gaze samples or nystagmus saccade end points allows the estimation of intended fixations, which in turn allows calibration and gaze sample correction. The proposed algorithm can be used online (for gaze contingent studies) and offline (to estimate gaze samples after the experiment) and is suitable for other difficult-to-calibrate populations. The validity of the procedure and its implementation is demonstrated in patients with (infantile) involuntary nystagmus.

Investigating the Role of Prediction in Trans-Saccadic Perception: Peripheral Preview Reduces the Fixation-Locked N170

Christoph Huber-Huber[1], Antimo Buonocore[2], Clayton Hickey[1] and David Melcher[1]
[1]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy
[2]Werner Reichardt Centre for Integrative Neuroscience, University of Tübigen, Germany

The world appears stable despite saccadic eye movements likely because the efference copy of the motor plan is used to predict perception after a saccade. Violating this prediction should be detrimental to post-saccadic perception resulting in a prediction error signal that is modulated by the frequency of a prediction violation. Here, participants made cued saccades to one of the two lateral upright or inverted faces. During the saccade, the faces could change their orientation (invalid) or remain the same (valid preview). Valid trials led to a behavioral benefit and reduced fixation-locked P1, N2, and N170 components, demonstrating a general preview reduction consistent with a prediction error signal. However, the preview reduction was not modulated by the frequency of valid and invalid trials within blocks as evidenced in a whole-scalp Bayes analysis. This pattern of effects constrains theories about the role of prediction in trans-saccadic perception.

Does Retinal Image Motion Arising From Smooth Pursuit Eye Movements Systematically Influence Temporal Perceptual Grouping?

Adela S. Y. Park, Phillip A. Bedggood, Andrew B. Metha and Andrew J. Anderson
Department of Optometry and Vision Sciences, The University of Melbourne, Australia

Briefly presented stimuli can reveal the lower limit of retinal-based perceptual stabilisation mechanisms. This is demonstrated in temporal grouping where alternate row or column elements of a regular grid are presented over two successive display frames with an imperceptible temporal offset. Grouping results from a subtle shift between alternate grid elements due to incomplete compensation of small eye movements occurring between the two presentation frames. This suggests that larger shifts should improve grouping performance. However, small eye movements follow a random walk, making this difficult to systematically explore. Here, we established a systematic relationship between retinal image motion and perceptual grouping by presenting alternate grid elements (untracked) during smooth pursuit of known velocities. Our results show grouping performance to improve with increasing pursuit velocity. Any potential compensation by extraretinal signals does not seem to occur.

Gaze Position Changes Across Blinks Carry Over to Saccade Landing Errors

Wee Kiat Lau[1], Thérèse Collins[2] and Gerrit Maus[1]
[1]Department of Psychology, Nanyang Technological University, Singapore
[2]Laboratoire Psychologie de la Perception (UMR CNRS 8242), Université Paris Descartes, France

Eye blinks lead to small changes in gaze position that can adaptively reduce fixation errors. However, it is unknown how the oculomotor system represents these gaze changes. Here, we test whether gaze changes across blinks are tracked via a fast, efference copy-based updating process or through slower, visually based means. Participants fixated on a spot and blinked. Fixation stepped 0.7° sideways during the blink to induce gaze position changes. Within 0.5 seconds after the blink, a target appeared in one of the nine possible locations and participants executed a saccade. Saccade landing errors were biased in the same direction as the gaze change across the blink. The target position was not available pre-blink, so one would expect the saccade to be planned based on the gaze position after the blink. Nevertheless, the gaze error introduced by the blink carries forward to the saccade landing position, indicating that the gaze position after the blink was not updated before executing the saccade.

Memory-Guided Microsaccades

Konstantin F. Willeke[1], Xiaoguang Tian[1], Antimo Buonocore[1], Joachim Bellet[1], Araceli Ramirez-Cardenas[2] and Ziad Hafed[1]
[1]Physiology of Active Vision Laboratory, Werner Reichardt Centre for Integrative Neuroscience, Germany
[2]Department of Neurosurgery, University of Iowa Hospitals and Clinics, IA, USA

Despite evidence to the contrary, microsaccades are overwhelmingly described as "involuntary" and "spontaneous." This is likely due to a lack of explicit demonstrations of a specific ability to voluntarily trigger microsaccades at will. Here, three monkeys and seven humans performed a "memory-guided microsaccade" task in which individual microsaccades (of amplitudes even 30′) were easily triggered: (a) "on demand," based on an arbitrary "go" instruction, (b) without special training, (c) without visual guidance by a stimulus, and (d) in a spatially and temporally accurate manner. All subjects naturally generated these movements and in a manner similar to normal visually guided microsaccades. In two monkeys, we also identified

superior colliculus neurons exhibiting saccade-related bursts exclusively for voluntary microsaccades and not for similarly sized visually guided movements. Our experiments demonstrate behavioral and neural evidence for voluntary control over microsaccade generation.

Assessing the Dynamic Visual Processing of Informative Local Features With Eye Movements

Anna Montagnini[1], A. P. Benini[1] and Maria Michela Del Viva[2]
[1]Institut de Neurosciences de la Timone, Aix-Marseille Universitè, France
[2]NEUROFARBA, University of Florence, Italy

Voluntary saccadic eye movements optimize visual analysis through the dynamic sampling of the most informative regions in the scene. By implementing a constrained maximum-information model to natural images, we selected a set of local patterns (3×3 black/white pixels) as candidate informative (or salient) patterns. We tested the role of these model-defined informative patterns for (a) a simple two-alternative forced choice (2AFC) saccade experiment between synthetic compounds of salient and non-salient patterns and (b) a more complex image-discrimination task allowing participants to freely explore visual arrays to extract global and local information. Our results point to a robust, automatic gaze orientation toward the informative patterns. This fast selection across a large visual space is often followed by a more accurate second saccade in the 2AFC task. In addition, different individual strategies emerge under more complex search conditions, especially when the fine analysis of local information is required.

The Self Can Hold Attention: Evidence From Saccadic Eye Movements

Mario Dalmaso, Luigi Castelli and Giovanni Galfano
DPSS, University of Padova, Italy

Two experiments were carried out to assess whether schematic stimuli associated with either the self or a stranger can shape attention holding. First, participants completed a manual matching task in which they were asked to associate the self and a stranger with a triangle versus a square. Then, they performed a saccade from the centre of the screen towards a peripheral target while either the triangle or the square were centrally presented. In Experiment 1, saccades had to be performed on each trial while in Experiment 2 saccades had to be performed only when the central shape was associated with either the self or the stranger, according to block instruction. Participants were slower to initiate a saccade away from the central shape when this was associated with the self rather than with the stranger, but this pattern of results emerged only in Experiment 2. These data suggest that stimuli associated with the self through episodic learning can hold attention in human observes.

Influence of Eye Dominance on Oculomotor and Attentional Selection

Jérôme Tagu, Karine Doré-Mazars and Dorine Vergilino-Perez
Vision Action Cognition Lab, Paris Descartes University, France

The dominant eye is the one used to perform a monocular task. There is an advantage of the hemifield controlateral to the dominant eye for both motor (higher saccade accuracy) and perceptual (faster detection) performance. The current study examines the influence of eye dominance in a dual-task paradigm. It involves a saccade and a discrimination task to one of the six locations possible, enabling the dissociation between saccade target and discrimination target. Four groups of participants are tested, according their eye dominance and eye dominance strength. We investigate whether the higher saccade accuracy in the hemifield controlateral to the dominant eye is due to enhancement of the target location or to inhibition of the distractor locations. Preliminary results on discrimination performance suggest that eye dominance is associated to attentional asymmetries between visual hemifields.

Filling-In and Perceptual Reliability in the Scotopic Foveal Scotoma

Alejandro Gloriani and Alexander Schütz
Department of Experimental and Biological Psychology, Philipps-University Marburg, Germany

To optimize their responses, humans need to assess the received sensory information. Sometimes, however, percepts are inferred only from the context and therefore intrinsically uncertain. Here, we investigated the filling-in process in the scotopic foveal scotoma and trans-saccadic integration in scotopic vision. Striped stimuli were presented in presaccadic peripheral, postsaccadic foveal and trans-saccadic conditions. Stimuli were circles with independently striped center and surround, either vertical or horizontal. When both center and surround were presented simultaneously, the stripes could be either parallel or orthogonal. Participants had to judge the orientation of the center. We analyzed *d*-primes and bias and found that the perception in the foveal scotoma was biased by the

surround. This inferred foveal information from the surround, however, was not treated as reliable and did not bias perception in the trans-saccadic condition.

Age Effects on Visual Sensitivity for Luminance and Chromatic Stimuli During the Execution of Saccadic Eye Movements

Doris Braun[1], Alexander Schütz[2] and Karl Gegenfurtner[1]
[1]Department of Psychology, Giessen University, Germany
[2]Department of Psychology, Marburg University, Germany

Saccadic eye movements dynamically modulate our visual perception: Before and during saccades, visual contrast sensitivity is strongly reduced. Visual contrast sensitivity during fixation is also affected by age. Here, we investigated how saccadic suppression changes with age. Thirty subjects from 8 to 79 years were tested. We measured contrast sensitivity for luminance and isoluminant chromatic lines flashed during fixation or during horizontal 10° saccades. During saccades, the reduction of contrast sensitivity for luminance stimuli increased from 54.5 ± 3.9% standard error (*SE*) for young subjects (average age 23 years) to 68.9 ± 3.2% *SE* for senior subjects (average age 70.8 years). Contrast sensitivity for color stimuli decreased from 54.1 ± 4.4% *SE* for the younger subjects (mean age 25 years) to 67.7 ± 3.8% *SE* for the older subjects (mean age 68.9 years). These results suggest that visual sensitivity during saccades is modulated by age and that the strength of saccadic suppression increases with age.

Spatial Modulations of the Visual First-Order Feature as the Targets for Attention

Denis Yavna and Vitaly Babenko
Department of Psychophysiology and Clinical Psychology, Southern Federal University, Academy of Psychology and Educational Sciences, Russia

Visual second-order filters detect spatial modulations of local features. This operation is important for texture segmentation. But is it the role of the filters to solve this one task? Our goal is to determine their role in object detection. Photos of 100 objects were processed by our computer second-order filter model, which independently extracted the areas with local maxima of modulation of contrast, orientation, or spatial frequency. Each object was reconstructed in three versions (from the areas containing the modulations of one dimension). Three images of the same object were placed around the center of the stimulus. The subject's task was to determine the location of three images in each of 100 stimuli. The eye tracking allowed to reveal that images that consisted of contrast or orientation modulations had priority in competition for attention. The images restored from spatial frequency modulations were significantly worse in ability to attract attention. This study was supported by RFBR # 17-06-50141.

Up and Down, Left and Right: Asymmetries in Eye Movements During Facial Encoding

Fatima M. Felisberti, Sabira Mannan, Liam Currie, Christopher Ballard and Thomas Ghiesing
Department of Psychology, Kingston University London, UK

Faces encoded in the upper visual hemifield (VHF) were recalled more accurately than the ones encoded in the lower VHF, and such asymmetries can be modulated by contextual factors. Eye movements measured as dwell time (%DT) and fixations (%Fix) during the memorisation of three sets of four faces were recorded using EyeLink. Each face was placed in one of the four quadrants and each face set was tagged with cheating, cooperative or neutral behaviours. Findings showed that behavioural tags had no effect on overall eye movements or accuracy in a simplified face recognition test. However, %DT and %Fix were significantly higher for faces presented in the upper than in the lower VHF (especially the top left quadrant) and in the left than in the right VHF. These findings confirm previous reports about asymmetries in face recognition accuracy linked to the encoding VHF and are discussed in terms of cultural referential and factors modulating eye movements.

Unconscious Information Processing Affects the Fixational Eye Movements and Pupil Diameter

Kengo Tane and Bruno Laeng
Department of Psychology, University of Oslo, Norway

We recorded the fixational eye movements and pupil diameter during a paired-associates task and compared the implicit-learning condition to the explicit-learning condition and the nonlearning condition. During the learning phase, participants were presented the stimulus pairs (color and abstract figures) explicitly or implicitly (by using continuous flash suppression technic). During the test phase, correct pairs and incorrect pairs were presented side by side. In nonlearning condition, the pairs that were not presented during the learning phase were used. Results showed that participant's fixational eye

movements were biased toward the chosen stimulus, before the decision, only in the implicit learning condition. The average pupil diameter during decision was significantly different between the nonlearning condition and the other two conditions. These results suggest that the unconscious information processing can affect the involuntary eye movements.

Parallel and Extra-Foveal Processing of Object Semantics During Visual Search

Francesco Cimminella, Sergio Della Sala and Moreno Ignazio Coco
Human Cognitive Neuroscience, Psychology, University of Edinburgh, UK

Controversy in vision science has stemmed from contrasting evidences about the time course of high- (semantics) and low- (saliency) level visual processing and the regions of the visual field which are involved (foveal vs. peripheral). In this eye-tracking visual search study, we contribute new findings to this debate by examining the interplay between object semantics and low-level visual saliency using object arrays of different size (3, 5 and 7). Our data show that when the critical object is semantically unrelated with the other objects in the display, it has significantly higher probability of being first fixated (i.e., immediate fixation) than when semantically related. This effect was consistently found for increasing set sizes. Visual saliency played no role in any of the measures examined. We conclude that object semantics can be extracted 'pre-attentively' (in extra-fovea) and in parallel (at first fixation) across the visual field, independently of low-level visual saliency.

The Effects of Interletter Spacing on Eye Movements During Natural Reading in Dyslexic and Control Adults

David Farkas, Zoltán Vidnyánszky and Béla Weiss
Brain Imaging Centre, Research Centre for Natural Sciences, Hungarian Academy of Sciences, Hungary

Recent studies found that increased letter spacing aids dyslexic subjects in reading. However, still very little is known about the effects of letter spacing on eye movements during natural reading. Here, we investigated the effects of interletter spacing on saccade amplitude (SA) and fixation duration (FD) in dyslexic and control adults. Participants read independent sentences with five different spacing levels. We found that reading speed was significantly lower for dyslexics, and it significantly decreased in both groups for larger spacings. SA increased with spacing in both groups, but on average, it was larger in the control group. FD was larger in the dyslexic group and showed a decreasing pattern in both groups as spacing increased. Interaction and post hoc analyses revealed stronger group effects for FD and SA in smaller and larger spacings, respectively. Our results delineate the oculomotor basis for letter spacing modulation of reading speed and its alterations in dyslexia.

Eye-Movement Correlates of Fixation-Related EEG Activity in Natural Reading

Ádám Nárai, Zoltán Vidnyánszky and Béla Weiss
Brain Imaging Centre, Research Centre for Natural Sciences, Hungarian Academy of Sciences, Hungary

Analyzing brain mechanisms of reading under natural circumstances is an emerging research topic. However, in such experiments, eye movements can strongly affect fixation-related EEG activity (FREA) and may also correlate with variables of interest, presumably making difficult to separate experimental effects from those of eye-movement covariates. To this end, we investigated the effects of saccade amplitude and fixation duration on FREA as well as their correlation with letter spacing during natural reading. Using hierarchical linear modeling, we found significant spatio-temporal effects of eye-movement covariates on FREA. Furthermore, despite the observed linear correlations between letter spacing and saccade amplitudes, effects of letter spacing were found to be robust against such moderate level of multicollinearity. We conclude that assessment of correcting for potential effects of eye movements is essential for analysis of fixation-related brain activity.

Predicting Fixation Densities Over Time From Early Visual Processing

Heiko Schütt[1], Lars O. M. Rothkegel[2], Hans A. Trukenbrod[2], Ralf Engbert[2] and Felix Wichmann[1]
[1]Neural Information Processing Group, University of Tübingen, Germany
[2]Department of Experimental and Biological Psychology, University of Potsdam, Germany

Low-level saliency is often cited as a factor driving the choice of fixation locations of human observers, based on the (partial) success of saliency models to predict fixation densities in free viewing. To test this hypothesis more directly, we analyse a number of saliency models as well as the theoretical limits for predictions over time. The fixation density in free viewing is not stationary over time but changes over the course of a trial. The first saccade is biased towards the image centre but is nonetheless

influenced by image content. Starting with the second fixation, the fixation density is similar to but more concentrated than later fixation densities and predictions profit from high-level image information. From there, the fixation distribution broadens until it reaches a stationary distribution around the 10th fixation. Taken together, these observations argue against low-level saliency as a mechanistic explanation for eye movement control after the initial-orienting reaction.

Fixational Eye Movements in Uncorrected Vision

Katharina Rifai[1], Denitsa Dragneva[1] and Siegfried Wahl[2]
[1]Institute for Ophthalmic Research, University of Tuebingen, Germany
[2]Carl Zeiss Vision International GmbH, Germany

Many medical examinations of ocular properties rely on stable fixation during measurement. However, a significant amount of measurement procedures require fixation during uncorrected vision. For fully corrected or emmetropic vision, fixational properties have been described in detail. But until now, fixational properties have not been systematically characterized under refractive error. In the current study, fixation of 20 subjects with myopic and hyperopic refractive errors was evaluated. Subjects repeatedly fixated a standard laser speckle target, used in many optical devices, such as the Zeiss Visufit 1000, for a duration of 3 seconds. Fixational eye movements were recorded with the Eyelink 1000 plus, and fixational properties, namely, amplitude of fixational microsaccades, and rate of fixational microsaccades were evaluated, together with a measure of fixational dispersion. Systematic changes in fixational properties were found with increasing refractive error.

Neural Correlates of Refixation in Natural Viewing Behavior

Andrey Nikolaev, Radha Nila Meghanathan and Cees van Leeuwen
Laboratory for Perceptual Dynamics, KU Leuven – University of Leuven, Belgium

In natural vision, eye movement sequences include returns to earlier visited locations. These revisits, or refixations, offer additional occasions for information uptake, compensating for short-term visual memory deficits. Despite the ubiquity of refixations, their neural control mechanisms have not been studied before. We used eye tracking combined with electroencephalogram (EEG) during a task, involving unrestricted visual search for a contour in a field of Gabor elements. An EEG signal that distinguished refixations from ordinary fixations occurred in the presaccadic interval, that is, when attention shifts to the next saccade target. By contrast, no distinctive EEG signal occurred in the postsaccadic interval, the interval related to visual information acquisition during fixation. Thus, a special mechanism for refixation control operates in the attention-related stage of saccade planning, when latent representations of memory-deficient locations may be brought into the focus of attention.

Cognitive Effects of Inclusive Interfaces in Written Tests

Mark Pileggi[1], John C. Herbert[2] and Anis Ur Rehman[3]
[1]Department of General Sciences – English, Kobe City College of Technology, Japan
[2]Department of General Studies – English, National Institute of Technology, Akashi College, Japan
[3]Department of Liberal Arts and Sciences, National Institute of Technology, Kagoshima College, Japan

A variety of learning tools have been devised, ranging from online quizzes to games using small console devices such as smart phones, tablets, and so forth. In such robust learning environments, cognitive science research suggests that making these technologies available to meet a wider range of students' interests and abilities has a significant impact on learning. Likewise, as many individuals join the classroom with specific learning difficulties, it is necessary to prioritize inclusive practices that utilize the options presented by technology. Moreover, there is a need to provide more effective test interfaces for all students. In this study, the effects of background color and text formatting of visual interfaces on students' test performances were investigated using eye-tracking equipment. Initial findings revealed that students' performances were slightly improved, and they consumed less time on the tests when inclusive interfaces were used in comparison to conventional ones.

Amplitude of Saccades Is Modulated by the Nature of Visual Stimuli and Saccade Accuracy in Saccadic Choice Tasks

Louise Kauffmann[1], Lea Entzmann[2], Carole Peyrin[1], Alan Chauvin[1] and Nathalie Guyader[2]
[1]Department of Psychology, Laboratoire de Psychologie et Neurocognition – Gipsa-Lab, France
[2]Image-Signal, Gipsa-Lab, France

Studies using saccadic choice task (where participants have to initiate saccades toward a target image presented along

with a distractor image in the opposite visual field) showed faster and larger saccades toward face targets than other stimuli. Error saccades were also found to be shorter than correct ones, suggesting an online correction. To better control saccade amplitudes, we did a new saccadic choice experiment in which participants had to saccade toward a central cross added on images. We still observed hypometric saccades (a) for saccades toward vehicles compared to faces and (b) for error saccades, which were followed by corrective saccades with very short latencies. These results suggest a parallel programming of saccades toward both images. The two saccade programs interact and interfere with each other and would be weighted by the saliency of the target, affecting saccade amplitude.

Presaccadic Spatiotopic Updating Across Visually Guided Saccades Investigated With Time-Resolved MEG Classification

Jasper Fabius[1], Alessio Fracasso[2], David Acunzo[3], Davide Deflorio[3], Stefan Van der Stigchel[1] and David Melcher[3]
[1]Department of Experimental Psychology, Utrecht University, the Netherlands
[2]Institute of Neuroscience & Cognition, University of Glasgow, UK
[3]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy

Saccades introduce frequent changes in visual input. Yet, visual perception seems introspectively continuous. How does perceptual continuity arise? With time-resolved magnetoencephalography (MEG) classification, we examined the hypothesis that retinotopic representations (RRs) are updated predictively before saccade onset. A grating was presented at the same spatiotopic location across a saccade. We decoded spatial frequency and observed reliable decoding for the time period between 50 milliseconds and 200 to 400 milliseconds after stimulus onset or after saccade offset: the current RR. If these RRs are updated presaccadically, then a classifier—trained with separate data, obtained while subjects fixated the post-saccadic fixation point—might decode spatial frequency above chance before saccade onset: the future RR. However, this cross-condition decoding was very weak, suggesting that pre-saccadic MEG activity related to spatial frequency is driven primarily by feedforward processing rather than predictive updating.

Near-Far Pupil Response Elicited by Illusory Depth: Evidence for Top-Down Pupil Control

Michael Wagner[1], Ronen Hershman[2] and Avishai Henik[3]
[1]Industrial Engineering & Psychology Department, Ariel University, Israel
[2]Department of Cognitive and Brain Sciences, Ben-Gurion University of the Negev, Israel
[3]Zlotowski Center for Neuroscience, Ben-Gurion University of the Negev, Israel

Pupil response to brightness (light reflex) and to near-far distance accommodation (near effect), are well-known phenomena. Recent studies indicate possible control of pupil size by top-down processes. In this study, we asked whether the pupil's near-far effect could also be elicited by illusory perspective depth cues. Wire-frame perspective "tunnel" displays were used to construct the spatial three-dimensional environment, leading from "near" either to the "far" right or to the "far" left screen directions. The participants' task was to respond to upper or lower target locations, presented at the "near" or at the "far" end of the perspective tunnel. Our results revealed relative pupil dilatation when participants' gaze fixated on "far" targets, as compared to fixation on "near" targets. Our findings support the hypothesis of possible top-down, precept-driven control of pupil response.

Automated Analysis of BR-OKN Facilitates Large Cohort Studies

Stepan Aleshin[1], Gergő Ziman[2], Ilona Kovács[2] and Jochen Braun[1]
[1]Institute of Biology, Otto-von-Guericke-Universität Magdeburg, Germany
[2]Institute of Psychology, Pázmány Péter Catholic University, HAS-PPCU, Adolescent Development Research Group, Hungary

When binocular rivalry (BR) is induced by opponent horizontal motion, smooth pursuit phases of optokinetic nystagmus (OKN) typically reflect the perceived motion. We perfected this neat way to monitor phenomenal rivalry into an automated analysis of eye recordings from large and heterogeneous observer cohorts. Removal and interpolation of blinks and saccades yield a continuous record of smooth pursuit even from idiosyncratic oculomotor patterns. We validated our analysis by comparing ocular responses and volitional reports under BR and under "replay" conditions (i.e., physical reversals of image motion) for different developmental and patient populations. While faster than volitional reports, ocular responses are degraded by reduced alertness under "no task" conditions. We conclude that automated processing of recordings facilitates comparative studies of binocular rivalry in healthy, developmental, and patient populations.

This study was funded by DFG BR987/3 and NKFI NN110466.

Prisoner's Dilemma: What Will You Choose—Betrayal or Cooperation? An Eye-Tracking Study

Mariia Oshchepkova
Department of Psychology, Lomonosov Moscow State University, Russia

The aim of my work was to find out the relationship between the decision to cooperate or betray and the eye movements characteristics. It is shown that the characteristics of eye movements provide valuable information for studying cognitive processes. Thirty-two participants (13 males, 19 females, 18–23 years) took part in the experiment. The "Prisoner's dilemma" in modification of Axelrod was presented for 15 times. The participant's task was to make a choice between cooperation and betrayal and to score the maximum number of points that were charged for the choice. Registration of eye movements is carried out in monocular mode using the SMI iViewXTM Hi-Speed 1250 tracker. The results show that with the betrayal of another prisoner after cooperation and with your betrayal after the second prisoner betrayal, the number of fixations and saccades significantly increases; with your betrayal after the cooperation of another prisoner, the same characteristics significantly reduce.

Pupillary Changes Reflect Visual Spatial Attention Modulated by Emotional Sounds

Satoshi Nakakoga[1], Hiroki Kajita[1], Hiroshi Higashi[1], Shigeki Nakauchi[1] and Tetsuto Minami[2]
[1]Department of Computer Science and Engineering, Toyohashi University of Technology, Japan
[2]Electronics-Inspired Interdisciplinary Research Institute, Toyohashi University of Technology, Japan

In our daily life, our visual attention is often modulated by environmental sounds, especially emotional sound. Previous study showed that the modulation of visual spatial attention is related to the valence of the sound cues by investigating the reaction time. However, it has not been clarified whether visual attention is automatically captured by emotional sounds before the process as reflected in reaction time. In this research, we used a visual stimulus divided into a bright and a dark half so that we can extract the direction of spatial attention by pupil diameter. Emotional sounds were presented to one of the both ears, and we estimated how emotional auditory cues modulate visual attention modulated by analysis of pupillary changes. As a result, pleasant sounds shifted a spatial attention to the presented side of the cues. These results indicate that pupillary changes are useful index showing emotional sounds cause cross-modal modulation in spatial attention.

The Effect of Verbalization on the Eye-Movements During Repeated Viewing of the Paintings

Veronika Prokopenya
Laboratory for Cognitive Studies, Saint Petersburg State University, Russia

Recent eye-tracking studies showed that complex scene processing can be divided in two stages: the ambient viewing, characterized by short fixations and long saccades, followed by focal viewing—longer fixations and shorter saccades. In our Experiment 1, subjects were looking at the painting, then half of them composed its verbal description, and the rest had a nonverbal task. Then, both groups reobserved the image. All subjects demonstrated both stages of processing during the first viewing, while the gaze pattern of the repeated viewing differed between groups. Subjects without verbalization continued the focal processing, and those who had verbalized the painting began its reviewing with the ambient processing. Experiment 2, in which we manipulated four verbal and nonverbal tasks, showed that every kind of verbalization associated with the image affected its reperception, demonstrating the pattern of ambient processing in the beginning of the second viewing. This study was funded by RSF#14-18-02135.

Different Fixation Patterns in Dynamic Scenes for Lightness and Stiffness Judgements

Lorilei Alley[1], Matteo Toscani[1] and Katja Doerschner[2,3]
[1]FB06 Psychologie und Sportwissenschaft, Justus Liebig University Giessen, Germany
[2]Department of Psychology, Justus Liebig University Giessen, Germany
[3]Bilkent University, Turkey

When judging lightness, human observers tend to fixate on regions with above average luminance, which is an optimal strategy for sampling visual information for this particular task. Here, we ask whether task demands modulate fixation patterns for other types of material property

judgements in dynamic scenes and whether fixations would be optimized for the task at hand. To investigate these questions, participants' gaze was tracked while they performed two-interval-forced-choice tasks comparing the stiffness and – in a separate block – the lightness of unfamiliar three-dimensional objects. For lightness judgements, we find that first fixations tended to be near the brightest region on the object and that they remained steady for the duration of the task. Interestingly, for stiffness judgements, fixations were less steady and tended to gravitate towards regions with high motion energy, which would be the optimal sampling strategy.

Eye Movement in the Process of Searching for Information on Websites: The Influence of Task Complexity and Webpage Design

Tatiana Zlokazova, Irina Blinnikova, Ivan Burmistrov and Sergey Grigorovich
Laboratory of Work Psychology, Lomonosov Moscow State University, Russia

The experiment simulated common web search type: the purchasing of tickets on a flight-booking site. The task was to search for return plane tickets within certain given parameters. Within-subjects factors were as follows: (a) the webpage design which influenced the search process: simultaneous or subsequent display of flight segments and (b) the task complexity which exerted different working memory loads. Each participant ($n = 10$) carried out 32 tasks (320 trials in total). The speed and accuracy of the search and the parameters of eye and cursor movement were measured. The results showed that the time taken and the dwell time spent in the key area of interest depended more on the task complexity. On the other hand, correlation of movement between eye and cursor was influenced only by the webpage design. The average fixation duration was influenced by both factors; it was grater in more complex tasks and with subsequent displays of flight segments. The study was supported by the RFBR # 17-06-00652.

Saccadic Adaptation Can Be Volitionally Controlled

Frauke Heins, Annegret Meermeier and Markus Lappe
Institute for Psychology, University of Muenster, Germany

Saccadic adaptation is usually assumed to be driven by an unconscious and automatic mechanism. In the current study, we investigated whether the instruction to inhibit the adjustment of saccadic amplitude in response to the occu3rence of a visual error signal, induced by the double-step paradigm, influences saccadic adaptation. We conducted the experiment with an intra-saccadic target step of 15% to 25% ($n = 8$) and 20% to 40% ($n = 8$) of the 12° amplitude of the primary saccade. When told to inhibit amplitude adjustment, gain change was close to zero for outward steps, but some adaptation remained for inward steps. Saccadic latency was not influenced by the type of instruction when the target was stepped inwardly, but for outward steps, latencies were larger in the inhibition condition. We conclude that volitional control can be exerted on saccadic adaptation and that it addresses the mechanism of target remapping, thus having a larger influence on outward adaptation.

Native Language Experience as a Determinant of Semantic Search Strategies: Eye-Movement Analysis

Maria Rabeson, Sofya Kirsanova and Irina Blinnikova
Department of Psychology, Lomonosov Moscow State University, Russia

The study aimed at intergroup differences in oculomotor patterns of Russian and Japanese students in verbal search tasks. Subjects searched for English words in letter matrices (15×15) presented on a screen for 40 seconds. Each matrix contained 10 words, horizontally and vertically oriented in equal proportion. Word frequency, length and emotional valence were controlled. During the search, the number of words found and eye-movement parameters were registered with SMI RED250. Oculomotor patterns of Japanese students showed shorter fixations, 185.6 milliseconds vs. 218.2 milliseconds at $F(1,205) = 29.15$, p 0.01, and higher saccade amplitudes, 10.64° vs. 4.99°. at $F(1;205) = 44.32$, p 0.01. Their visual strategy tended to be ambient and less efficient in this task as compared to that of Russians. Although the students were at the same level of English competence, the results can be explained through the differences in their linguistic experience. The study was sponsored by the RFBR research grant #16-36-00044.

Common Control Mechanisms Underlying Ocular Tracking and Interception of Partially Occluded Ballistic Trajectories Under Different Visual Contexts

Sergio Delle Monache, Riccardo Ingrosso and Gianfranco Bosco
Dipartimento di Medicina dei Sistemi, Università di Roma "Tor Vergata," Italy

With ocular tracking, we acquire detailed information about a moving target to achieve more accurate manual capture. To study how different visual contexts and target kinematics influenced eye and interceptive movements, in Experiment 1, 12 subjects tracked and intercepted a target moving within either a realistic or a neutral scenario, while in Experiment 2, other 12 subjects only tracked it. The target followed computer-simulated ballistic trajectory with natural gravity effects in the ascending portion and perturbed (0 g|2 g) or unperturbed (1 g) gravity conditions in the descending part. After the perturbation, targets were transiently occluded reappearing shortly before landing. In both tasks, saccadic and smooth pursuit parameters showed a higher anticipation in the realistic scenario—replicating the pattern observed with the interceptive responses in Experiment 1. These findings may reflect a common control mechanisms for eye movements and manual interception.

Mobile Eye Tracking in the Royal Academy of Arts – Analysing Scanpath Sequences in Jackson Pollock's Paintings

Jasmina Stevanov[1], Johannes Zanker[1] and Tim Holmes[2]
[1]Department of Psychology, Royal Holloway, University of London, UK
[2]Tobii Pro Insight UK, UK

This study was set out to describe commonalities in gaze patterns during extended viewing time (4 minutes) of abstract paintings in a museum setting. We recorded eye movements of 24 participants free viewing two Pollock paintings (*Mural* 1943 and *Blue Poles* 1952) in the Royal Academy. Unlike in a laboratory, experiments run in museums allow us to record extensive gaze displacements across large-scale canvases and use their amplitude to characterise viewing behaviour. Individual fixation sequences were converted into strings of letters corresponding to data bins and mapped to vector spaces. Strings were characterised by two features: alphabet size (A) corresponding to the number of data bins and repeating subsequences of sparsely occurring events (N). We trained support-vector machine classifiers using combinations of A (2–26) and N (1–10). The highest accuracy (87.5%) was returned for $A = 8$ and $N = 7$, that is, the two paintings were best distinguished using remarkably long seven-step eye movements sequences.

Covert and Overt Orienting to Social and Non-Social Cues in Early Deaf Adults

Claudia Bonmassar[1], Francesco Pavani[1], Cristina Caselli[2], Alessio Di Renzo[2], Luca Lamano[2], Tommaso Lucioli[2] and Wieske van Zoest[1]
[1]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy
[2]Language and Communication Across Modalities Laboratory, Institute of Cognitive Sciences and Technologies-National Research Council, Italy

Gaze and arrow cues cause covert shifts of attention even when they are uninformative. Interestingly, previous research suggested that deaf adults are not susceptible to uninformative gaze cues. The aim of this study was to investigate the role of oculomotor behavior in response to social and nonsocial cues in this group. We tracked the gaze of deaf and hearing observers performing a discrimination task with uninformative central cues (gaze vs. arrow), stimulus onset asynchrony (SOA) (250 vs. 750 milliseconds) and cue validity (valid vs. invalid) as within-subject factors. In both groups, the cue effect on reaction time was comparable for the gaze cue and arrow cue. Deaf observers responded slower and relied significantly more on eye movements than hearing controls, but overt saccadic performance did not differ in dependency of cue. This work suggests that the contribution of overt selection in central cueing of attention is enhanced in deaf adults and determines attentional performance, irrespective of cue type.

Longer Viewed, Better Remembered: Objects' Semantic Inconsistency and Information Accumulation in Real Environments

Sara Spotorno, Ioana Dragusin and Benjamin Tatler
School of Psychology, University of Aberdeen, UK

Semantics and perceptual factors are crucial in everyday life, but they have been examined in laboratory settings. We recorded eye movements and analysed inspection and recognition memory for colour and position of objects placed in different types of real rooms. The analysed objects were of high or low salience and semantically

consistent or inconsistent with the room. Salience had no effect. Inconsistent objects were not selected earlier than consistent ones, but they were fixated for longer. Memory for colour and position was better for inconsistent than consistent objects, but this arose exclusively from the longer inspection. Our results indicate that semantics override perceptual guidance in the real world. In line with the scene literature, they show that semantic inconsistency delays disengagement, without entailing any prioritisation before ocular selection. Moreover, they suggest that any memory benefit of semantics is a by-product of information accumulation during viewing.

The Transfer Function of the Oculomotor System for Small-Amplitude Slow Motion Trajectories

Julianne Skinner, Antimo Buonocore and Ziad Hafed
Physiology of Active Vision Laboratory, Werner Reichardt Centre for Integrative Neuroscience, Germany

Two main types of small eye movements occur during gaze fixation: microsaccades and low-velocity drifts. While microsaccade generation has been well studied, drift control mechanisms are unknown. Here, we explored whether smooth movements on the velocity scale of drifts can be generated systematically. Two monkeys tracked a spot moving sinusoidally (horizontal or vertical; 30′ amplitude; 0.1–5 Hz frequency). We obtained an oculomotor "transfer function" by measuring smooth eye velocity gain (relative to target velocity) as a function of frequency, similar to past work with large-amplitude smooth pursuit. Eye velocities as slow as those observed during drifts were clearly target-motion driven. Like with large-amplitude smooth pursuit, eye velocity gain varied with frequency. However, unlike with large-amplitude pursuit, exhibiting low-pass behavior, small-amplitude motion tracking was band pass with best gain occurring at 1 Hz. We suggest that smooth fixational drifts are controllable.

The Effect of Eye Movements on the Postural Control of Patients With Parkinson's Disease

Beomsu Kim and Nam-Gyoon Kim
Department of Psychology, Keimyung University, South Korea

The present study compared the effect of eye movements on postural control in 13 Parkinson's disease (PD) patients and 13 age-matched healthy adults. Participants viewed, from a distance of 1 m, a computer display of an oscillating object that continuously changed shape and reported the number of times the shape changed over each 60-second trial. Four oscillation rates were presented. Postural sway data were obtained by sensors attached to each participant's head, neck, and cervical spine. The effect of eye movement frequency on postural sway was minimal in the healthy adults, consistent with the view that postural control and suprapostural task are functionally integrated to facilitate the performance of suprapostural control tasks. By contrast, PD patients' showed greater and more variable postural sway, particularly in the anterior–posterior direction. It appears that PD patients' impaired postural control systems are no longer integrated functionally with their eye movement control.

A Study of Fixational Eye Movement Directional Parameters Using Hologram, Stereo, and 2D Image Atimuli

Taina Lehtimaki, Ronan G. Reilly and Thomas J. Naughton
Department of Computer Science, Maynooth University-National University of Ireland Maynooth, Ireland

We studied fixational eye movements when viewing holographic, stereoscopic, and two-dimensional stimuli of three-dimensional scenes. We detail the results of our study with five participants' fixational eye movements during natural viewing of specific features at different depths for the three types of stimuli. We define and show distributions for three fixational eye movement directional parameters: (a) absolute direction, (b) relative direction, and (c) disparity between left and right eye absolute directions. Our results show how distributions of movement directions of the eye vary gradually from slow (ocular drift and tremor) to fast (microsaccades) fixational eye movements. Thus, we propose that detection and classification of microsaccades may improve by also considering directional parameters. Our results are similar for all three different types of stimuli.

Gaze Cueing by Multiple People

Szonya Durant, Francis Lammas, Sophie Mason and Emma Salter
Department of Psychology, Royal Holloway, University of London, UK

We tested using, eye tracking, whether the attention shift due to the direction of gaze of a person (a gaze cue) is affected when we add multiple gaze cues. We photographed one, two, or three models gazing at one of the two objects (desk phone/keyboard) placed left or right of

them on a table. In control versions of the two- to three-model photos, only one model provided a gaze cue, the rest kept their eyes closed. The 3-second displays were viewed freely, with a fixation cross in between. We found a main effect of gaze cue direction: The gaze cued object was fixated more quickly and for longer. We also found a main effect of increasing model number: There was shorter overall fixation duration on the objects and it took longer to fixate them. We found that the proportion of time of fixation on the cued object increased with more models in the scene. All these effects also held in the control condition, suggesting the gaze cueing effect is driven by the gaze direction alone and not the number of gaze cues.

Probing Neural Decision-Making in Behavioral Models of Scanpath Prediction

Matthias Kümmerer, Thomas Wallis and Matthias Bethge
Centre for Integrative Neuroscience, University of Tübingen, Germany

A long-standing theory in the field of gaze prediction poses the existence of an image-dependent saliency map, which is combined with task information and scanpath history to decide on the target of the next saccade. However, most of the benchmarking work on fixation prediction does not attempt to model dependencies on the latter. Here, we develop a quantitative framework of neural decision-making to probe how dependent on image features the effect of the scanpath history is. To this end, we extend our state-of-the-art model DeepGaze II with features encoding the scanpath history, and a readout architecture that allows us to separate the image-dependent saliency processing and the subsequent history-dependent fixation selection. By changing the number of features (saliency maps) passed into the second stage, we can control the feature specificity and complexity of the effects of scanpath history on fixation selection process in this model of neural decision-making.

Eye-Tracking Study of Reading Polycode Texts: Evidence From Russian

Tatiana Petrova[1] and Natalia Kalugina[2]
[1]Laboratory for Cognitive Studies, Saint Petersburg State University, Russia
[2]Department of Russian as a Foreign Language, Saint Petersburg State University, Russia

Visual representation of information is getting more actual nowadays. We investigate how a text type influences the process of reading and how readers integrate text–figure information when reading and understanding "polycode" texts. Four texts in infographics were extracted from Russian newspapers and then converted into regular text format. The participants were asked to read two texts in infographics and two verbal texts. Eye movement data from 18 Chinese students learning Russian as a foreign language indicate that their reading patterns were text directed even while processing infographics. Their comprehension was also controlled by off-line methods (the method of subjective scaling, question–answer method, and key words method). The overall results of the study show that the influence of the type of a text affects the text flow as you get closer to the proficient reader: the higher the level of development of reading skills, the greater the influence of the "text type" factor.

Saccadic Suppression of Natural Image Transformations

Maryam Keyvanara[1] and Robert Allison[2]
[1]Electrical Engineering and Computer Science, York University, Canada
[2]Centre for Vision Research, York University, Canada

During a saccade, the image of the environment moves rapidly across the retina. However, due to saccadic suppression, our perception of motion is attenuated and our visual sensitivity is suppressed. We explored whether the extent of saccadic suppression depends on the type of image transformation. Participants observed three-dimensional scenes and made a vertical or horizontal saccade to follow a target object. During this saccade, the entire scene was translated or rotated along one of the canonical directions. After each trial, participants indicated the direction of the scene change in a forced-choice task. Change detectability depended on the magnitude and type of transformation. During vertical or horizontal saccades, users were least sensitive to vertical or horizontal translations, respectively, and most sensitive to rotations along the roll axis. We conclude that saccadic suppression affects natural image transformations that occur during whole body and head movement through our environment.

Faces

Subliminal Processing of Emotional Faces Requires Attention

Jeesun Kim, Simone Simonetti and Chris Davis
The MARCS Institute, Western Sydney University, Australia

We examined whether face emotion processing can occur without awareness or without attention. A masked-priming paradigm was used by rendering each prime stimulus (a happy or angry face, matched on low-level image properties) unavailable for conscious report. Spatial attention was manipulated by having 80% of targets on one side (attended) and 20% on the other (unattended); with primes and targets on opposite sides, 20% of primes were attended, 80% unattended. Prime and target emotion matched (50%) or mismatched (50%); primes and targets were same faces (10 males; 10 females) but had different poses. Participants ($N = 22$) classified target faces as 'happy' or 'angry'; response times and accuracy were measured. Responses to attended targets were faster and more accurate than to unattended ones, indicating a successful manipulation of attention. Significant masked priming was found only for attended face primes, suggesting subliminal processing of face emotion occurs but requires attention.

Investigating Implicit and Explicit Facial Emotion Perception in Children With and Without Autism Spectrum Disorder

Stephanie Van der Donck[1], Sofie Vettori[2], Milena Dzhelyova[3], Jean Steyaert[4], Bruno Rossion[3] and Bart Boets[2]
[1]School of Biomedical Sciences, KU Leuven, Belgium
[2]Center for Developmental Psychiatry, KU Leuven, Belgium
[3]Psychological Sciences Research Institute and Institute of Neuroscience, UCL, Belgium
[4]UZ Leuven, Belgium

Being able to perceive facial expressions quickly is crucial for social interactions. We combined fast periodic visual stimulation (FPVS) with scalp electroencephalography (EEG) and eye tracking to gain more insight in the perception of expressive faces in children with and without autism spectrum disorder (ASD). FPVS EEG elicits a brain response at exactly the same frequency of visual stimulation when expressions are perceived in a stream of neutral faces. Additionally, we investigated whether this neural index of expression discrimination relates to behavioural indices of facial emotion processing and scanning patterns of the faces. Our data show that children with and without ASD are capable to implicitly discriminate facial expressions. However, significantly reduced EEG responses in children with ASD compared to controls indicate an overall lower sensitivity to facial expressions. The implicit EEG data will be complemented with explicit behavioural expression processing data and eye-tracking data.

The Iron Lady Gets Emotional: Emotional Expressions Strongly Impact the Thatcher Illusion

Sandra Utz and Claus-Christian Carbon
Department of General Psychology & Methodology, University of Bamberg, Germany

Thompson described the Thatcher illusion: Upright faces with inverted eyes and mouths are perceived as grotesque but not if faces are inverted. We tested whether emotional faces modulate the illusion. A study using neutral, sad and happy faces revealed a reduced illusion for happy faces. Since happy faces differed in distinctive features (open mouth and visible teeth), a subsequent study tested the actual impact of such features by adding disgust with similarly distinctive but qualitatively different features, plus fear, surprise and anger as a control. Twenty-six participants evaluated the grotesqueness of 16 base faces showing these emotional expressions (thatcherised/non-thatcherised; upright/inverted). We observed again a reduced illusion only for happy faces, ruling out that it is just about distinctive features, but that it is specifically about features of happiness. This points to the extraordinary importance of happy face features which seem to be represented quite mono-orientedly.

Effects of Self-Referential Processing and Visual Similarity on Categorization of Morphed Faces

Garrett Cotter[1], David Tovar[1] and Mark Wallace[2]
[1]Department of Neuroscience, Vanderbilt University, TN, USA
[2]Department of Hearing and Speech, Vanderbilt University, TN, USA

Self-referential processing, the strategy of using oneself as a reference to aid in rapid object recognition, is often thought of in binary terms: "self" or "other." In this study, we investigated how visual similarities between participant and novel face stimuli help facilitate facial recognition. We photographed participant faces and then measured similarity between the participant's face and a set of control faces. Next, we created a series of gradual pairwise face morphs from control stimuli. Subjects were asked to select which control face the morph most resembled. We found that subjects were faster for categorizing faces that were more similar to their face ($p = .01$). We then morphed the participant's photograph with control stimuli. Here, the reaction time advantage for morphs visually similar to the participant was greater for the participant morphs than control morphs ($p = .01$). Together, these results suggest a continuum of self-referential bias in facial recognition.

Does Red Really Enhance the Perception of Anger?

Tarja Peromaa[1] and Maria Olkkonen[2,3]
[1]Department of Psychology and Logopedics, University of Helsinki, Finland
[2]University of Helsinki, Finland
[3]Durham University, UK

It has been suggested that the color red enhances the perception of anger in faces. However, the magnitude of this effect has not been quantified to date. We quantified the effect of facial color and background color on anger recognition in 20 naive participants with psychometric functions measured with the method-of-constant-stimuli, while facial hue or surround hue was varied. Morph sequences between neutral and angry faces were generated for four identities from the Umea University Database of Facial Expressions. In Experiment 1, the average chromaticity of the faces was shifted by ΔE 12/20 in CIELab color space (0°/90°/180°/270°). In Experiment 2, the hue of the surround was neutral, red, green, or blue (24°/162°/246°) with chroma 60/80. Both facial redness and surround redness enhanced perceived anger slightly—2 to 4 morph%. But, individually, only 25% of the participants showed reliable enhancement, calling into question the practical significance of red in emotion recognition.

fMRI BOLD Signal Dynamics During Perceptual Adaptation to Facial Emotional Expressions

Olga Korolkova[1], Valentin Sinitsyn[2] and Ekaterina Pechenkova[2]
[1]Department of Life Sciences, Brunel University London, UK
[2]Radiology Department, Federal Center of Treatment and Rehabilitation, Russia

We explored the brain correlates of perceptual adaptation to emotional faces – a behavioural phenomenon of judging ambiguous expressions as different from the adapted emotion. In event-related functional magnetic resonance imaging (fMRI) study, observers ($N = 20$) adapted to happy, sad or scrambled faces for 5 seconds and then judged intermediate morphs laying on individual categorical boundary as happy or sad. The trials without adaptation effect were excluded based on the responses. fMRI data were split in two halves to identify regions of interest (ROIs) with significant contrasts between emotional and scrambled adaptors in one half. Using the other half, we estimated the average blood oxygenation level-dependent (BOLD) signal change in ROIs in three types of adaptors. The results revealed increase in BOLD signal in left/right lateral occipital regions in scrambled compared to emotional adaptor condition, while adaptation to either happy or sad faces led to higher and prolonged activation in right posterior superior temporal sulcus, thereby supporting its primary role in social perception.

Body Size Estimation: The Influence of Visual Perspective

Anne Thaler[1], Sergi Pujades[2], Isabelle Bülthoff[1], Michael J. Black[2] and Betty J. Mohler[3]
[1]Human Perception, Cognition and Action, Max Planck Institute for Biological Cybernetics, Germany
[2]Perceiving Systems, Max Planck Institute for Intelligent Systems, Germany
[3]Technical University Darmstadt, Germany

Previous research on own visual body size estimation has only looked at estimates made by comparing own body size to a test body viewed in third-person perspective. However, people spend relatively little time seeing their body from this perspective as compared to the first-person perspective. Here, we asked whether the visual perspective on the body influences the accuracy of estimating own body dimensions. A three-dimensional virtual test body was presented in life size in immersive virtual reality either from a first- or from a third-person perspective. In a method of adjustment task, participants adjusted a varying number of the test body's dimensions (weight, leg length, arm span, hip width, and upper torso area) to match their own body. Results showed that participants were more accurate in estimating own body dimensions in the third-person perspective condition, suggesting that our mental body image is informed by viewing the own body as a whole, such as in a full-length mirror.

Does Appearance Transformation of an Avatar Face Changing Its Favorability Impressions Affect Human Recognition of Its Face?

Shigeru Akamatsu, Ryoko Yamada and Momoko Hada
Department of Applied Informatics, Hosei University, Japan

Through recent studies of image engineering, artificial transformation of impressions conveyed by avatar faces was achieved. We presented observers with pairs of such systematically impression-transformed faces randomly selected from the Todorov Face Database and asked them to choose the more favorable one to obtain favorability ratings for each synthesized face by Thurston's method of paired comparison. Based on the simultaneous monitoring results of their eye movements, we confirmed gaze bias in the sense that the gaze's cumulative duration increased within the face's area that was judged more

favorably, regardless whether the differences between the paired favorability ratings were large or small. We also investigated the relationship between the favorability of faces and recognition performance by humans and found that people generally failed to properly recognize faces as previously seen ones when impression manipulation reduced their favorability from the originally encoded face.

Reading Problems as Visual Problems: The Possible Roles of Visual Expertise and Feature-Based Processing

Heida Maria Sigurdardottir, Alexandra Arnardottir, Gudbjorn Larus Gudmundsson, Eydis Thuridur Halldorsdottir, Kristjan Helgi Hjartarson, Hilma Ros Omarsdottir, Anna Sigridur Valgeirsdottir and Árni Kristjánsson
Department of Psychology, University of Iceland, Iceland

Our recent work shows that dyslexic readers tend to have problems with face perception. We explored whether these might be due to difficulties with (a) visual expertise or (b) feature-based processing. For (a), we utilized the other-race effect, generally considered a consequence of greater experience with own- compared to other-race faces. If visual expertise is compromised in dyslexic readers so that their visual system is not effectively shaped by experience, then they might show a diminished other-race effect. However, dyslexic readers demonstrated face recognition problems regardless of race, and their other-race effect was comparable to that of typical readers. As for (b), disabled readers were on average worse than typical readers on feature-based processing of faces but were not disadvantaged on global form processing of faces. We speculate that disabled readers have specific problems with feature-based visual processing. Further work on this topic is currently underway.

Experimental Neuropsychological Evidence for Defective Configurational Face Processing in Posttraumatic Stress Disorder

Harald R. Bliem, Anja E. Walser, Christina J. Kirchler and Barbara H. Juen
Department of Psychology, University of Innsbruck, Austria

Although posttraumatic stress disorder (PTSD) is typically associated with fear-related impairments in social behavior and emotion, here we report on face-selective impairments in a case of PTSD revealed by fine-tuned face perception and recognition experiments. First, detection experiments with two-color face pictures at isoluminance and at varying luminance contrasts (from isoluminance to $\pm$ 80%) reveal a selective inability to perceive a face comparable to findings with prosopagnosic patients. Second, an inverted face recognition test showed no face inversion effect revealing failure to activate face-specific configurational processing. Finally, results show defective configurational face processing accompanied by a compensatory activation of local processes, which supports the intense control behavior to anticipate threatening situations in this case of PTSD. Findings are in accordance with a new neural model of global (magno-supported) and local (parvo-supported) face processing.

Influence of Face- and Observer-Based Factors on Social Perception of Faces

Mintao Zhao, Kaylee Eagleton and Kate Fuller
School of Psychology, University of East Anglia, UK

Our visual system is remarkably good at extracting socially relevant information from faces (e.g., trustworthiness, aggressiveness). Here, we investigated whether, and, if so, how face-based and observer-based properties affect such social perception of faces. We first tested how different parts of faces contribute to social judgements about faces (e.g., trustworthiness). We asked participants to rate faces shown as eyes region only, eyes region occluded or whole faces. We found the similar social perception of faces across the three conditions. We then tested whether self-reported personality affects participants' judgements about faces. We found that participants with higher self-reported trustworthiness judged faces as more trustworthy compared to those with low self-reported trustworthiness. This was not the case for extroversion and likeability judgements. Together, these results indicate that social perception of faces relies on both face- and observer-based information.

The Uncanny Valley of Agency: A Spatial Humancentric Bias

Sara Rigutti, Giulio Baldassi, Andrea Carnaghi, Marta Stragà and Carlo Fantoni
Department of Life Sciences, University of Trieste, Italy

Research addressing how individuals mentally represent events shows that the relatively more agentic/less pleasant item is placed on the left. So far, the process that account for this spatial bias remains unclear, being it driven by either agency or valence. We address this limitation with six stimulus couples resulting from four images with opposite agency/valence-based mental representation: from a

wood mannequin (no agency-right/humanlikeness-left), to a human (full agency-left/humanlikeness-right), with humans' avatar with/without facial features as intermediate items. Selection likelihood over pairs of couples was driven by agency not valence. It was larger for couples with the human and the avatar displayed to the left and the mannequin and the faceless avatar to the right. Such an ordering was consistent with a spatial humancentric bias with the human in the leftmost position, followed by the avatar, the mannequin, and finally the faceless avatar: an uncanny valley of agency.

Decoding the Development of Face Processing With EEG

Inês Mares[1], Louise Ewing[2], Emily Farran[3], Michael Papasavva[1], Fraser W. Smith[2] and Marie L. Smith[1]
[1]Department of Psychological Sciences, Birkbeck College, University of London, UK
[2]Department of Psychology, University of East Anglia, UK
[3]Department of Psychology and Human Development, UCL Institute of Education, University College of London, UK

Face processing is a vital social function known to mature during childhood. Studies examining the neural dynamics of this process in children typically focus on single event-related potential components. Here, we apply multivariate pattern analysis to quantify the neural information in the electroencephalogram (EEG) response. Children (6–11 years, $N = 53$) and adults ($N = 15$) completed an orthogonal target detection task while viewing upright and inverted faces and houses. We observe that concurrent neural recordings can be classified as a function of category (faces vs. houses) after less than 140 milliseconds for all age groups. Further, we can classify upright from inverted faces (an indicator of specialised face processing) even in the youngest group (6–7 years) for an extended period of over 180 milliseconds, a marker absent in their face selective N170. This provides new evidence of the neural underpinnings of face processing and highlights the benefit of considering the multivariate information in the EEG signal in addition to standard component analysis.

Encoding of Person Identity Information in the Occipital Temporal Area: A TMS Study

Charlotta Eick, Géza Gergely Ambrus, Lisa Röhrig, Sophie-Marie Rostalski, Catarina Amado and Gyula Kovács
Department of Biological Psychology and Cognitive Neurosciences, Friedrich-Schiller-Universität Jena, Germany

Memory for person identity (ID) contains three units: face, name and semantic information. Studies show that the right occipital face area (OFA) is involved in formation of ID-specific memory traces. This study ($n = 16$) examines whether OFA is also participating in acquisition of ID-specific semantic information. Unfamiliar faces were shown with acoustically presented names and jobs, while right OFA/vertex was stimulated by transcranial magnetic stimulation (TMS). Then, associated semantic information of each ID was retrieved by choosing the correct name/job. Associated jobs were better recalled than names. TMS of rOFA negatively affected recall of associated jobs relative to names, while it had no effect on recall of names. Our results indicate that besides low-level encoding of faces, OFA is likely involved in encoding of ID-related semantic information. This questions the serial processing model of face processing and suggests that ID recognition occurs in the occipito-temporal network.

Turning Heads—The Role of Changing Views and Expressions on Perceived Attractiveness of Unfamiliar Faces

Pik Ki Ho and Fiona Newell
School of Psychology, Institute of Neuroscience, Trinity College Dublin, Ireland

The perceived attractiveness of an unfamiliar face can be affected by its view and its expression. In the real world, heads move, but the effect of dynamic view changes on face attractiveness is poorly understood. Here, we investigated the effects of head turn direction and (angry and happy) expression on attractiveness ratings. We found an interaction between the direction of head turn and facial expression with higher ratings for smiling faces turning toward the observer and lowest ratings for angry faces regardless of the direction of head turn (Experiment 1). In Experiment 2, the relative duration of each face view during a turn was manipulated. Again, we found an effect of facial expression, but results also suggested that the temporal duration at which each face view was presented affected attractiveness ratings. Our results have implications for understanding facial attractiveness and suggest an important role for cues of social attention in modulating these perceptual judgments.

Face Recognition Memory Ability Directly Relates to Motivation to View Faces: Evidence From a Large Community Sample

Louise Ewing[1], Michael Papasavva[2], Inês Mares[2], Anne Richards[2] and Marie L. Smith[2]
[1]Department of Psychology, University of East Anglia, UK
[2]Department of Psychological Sciences, Birkbeck College, UK

Links between the motivation to engage with social stimuli and processing abilities for such stimuli are widely assumed but rarely directly tested. We explore the association between participants recognition memory for faces and the degree to which they find faces rewarding (measured via a motivated viewing paradigm for faces varying in orientation, emotion and attractiveness). Individuals scoring high on the Cambridge Face Memory Test (top quartile) work to view upright faces for longer than inverted, while those who score poorly (bottom quartile) show the opposite pattern. Correlating this preference for upright faces (via a difference measure) with face ability suggests a relationship across the entire sample, $r^2(377) = .089$, $p = .085$, driven by the higher performers, above median: $r^2(180) = .22$, $p = .003$. A linear mixed model confirms this relationship (increases in ability correspond to increased viewing of upright faces only) and hints at a mediating effect of emotional expression.

Superior Imitation Performance for Emotional Expressions Displayed in the Left Hemiface of the Model

Karola Schlegelmilch[1] and Werner Sommer[2]
[1]MPRG Naturalistic Social Cognition, Max Planck Institute for Human Development, Germany
[2]Department of Psychology, Humboldt - Universität zu Berlin, Germany

Perceptual advantages for facial emotion in the left visual field and the stronger expressivity of the left hemiface are attributed to a superiority of the right hemisphere for processing emotion and faces, implying that preferentially the less expressive right hemiface of one's counterpart is imitated. Here, 35 participants imitated images of faces expressing emotion. Computationally, assessed hemifacial movement was correlated between the participants and the depicted expressions. Imitation performance did not differ between the participants' hemifaces, but participants were found to imitate the model's left hemiface more precisely than the right hemiface ($p < .0001$). These results contradict the assumption of a general right hemispheric superiority for facial emotion. They could indicate an imitation-specific laterality of subprocesses as well as a perceiver's behavioral adaptation towards socially more relevant information displayed in a counterparts left hemiface.

Altered Functional Brain Connectivity During Visual Processing in Congenital Prosopagnosia

Kornél Németh[1] and Máté Baradits[2]
[1]Department of Cognitive Science, Budapest University of Technology and Economics, Hungary
[2]Department of Psychiatry and Psychotherapy, Semmelweis University, Hungary

Functional alterations of visual neural networks in congenital prosopagnosia (CP) are suspected but has never been tested. We analyzed graph-theory-based features of Phase Lag Index (PLI) coherence matrices of P1/N170/P2 visual event-related potential (ERP) components from theta to gamma frequency range in a large group of CPs ($n = 35$) and controls ($n = 32$). PLI is a measure of the asymmetry of the distribution of phase differences between two signals. Based on connectivity matrices, we estimated micro/meso/macroscale properties of each participant's network for face, and nonface stimuli in four frequency bands. However, traditional peak amplitude/latency and time–frequency analysis cannot reveal group differences, graph-theory-based features (e.g., modulatrity) in different frequency bands were significantly different between CP and controls. Our results suggest functional alterations of visual brain networks in CP first time based on graph-theory-based features of face-elicited ERPs.

Poor Image Quality Leads to a Conservative Bias When Matching Facial Identity

Harold Hill[1], Steven Roodenrys[1] and Colin Clifford[2]
[1]Department of Psychology, University of Wollongong, Australia
[2]Department of Psychology, University of New South Wales, Australia

Signal detection theory would predict that poor image quality would affect sensitivity but not necessarily bias when matching facial identity. However, it might be advantageous to adopt a different criterion for low-quality images to avoid false matches. Using images from the SCface database, we presented participants with a high-quality "mugshot" and a relatively good or a relatively poor quality image of either the same or a different person. Four variants of the experiment were run comparing either natural variation in captured image quality or

the effects of adding noise. Sensitivity was lower in the poor condition, but there was also a consistent trend for participants to adopt a more conservative criterion when matching poor quality images. However, this effect of image quality on bias was much less than individual differences in bias. Implications for an optimal strategy for matching low-quality images and for comparing bias when sensitivity differs are considered.

Perception of Self-Face and Other-Face Attractiveness

Anna Pichugina and Galina Menshikova
Faculty of Psychology, Lomonosov Moscow State University, Russia

It was revealed that the size of eyes and lips are important characteristics of face attractiveness. This study aims to investigate the impact of these factors on how people perceive attractiveness of their own face and other faces. The participants involved were 10 Japanese students who are all familiar with each other. Their portraits were taken, and, in each photo, the eyes and lips were magnified, shrunk, or kept as original. The first series of the experiment used photos with modified eyes, and the second series, with modified lips. Participants were asked to choose a photo that closely resembled the real face, while eye movements were being recorded. The results show that for their own face, participants often chose smaller eyes and original size of lips, while for other faces, participants often chose original size of eyes and shrunk lips. Duration and number of fixations on their own and other faces did not significantly differ. This study was supported by RFBR, project #18-013-01087.

Face Inversion Effect and Eye Movement Pattern in Male and Female During Facial Expression Recognition

Elizaveta Luniakova, Natalia Malysheva and Jahan Ganizada
Faculty of Psychology, Lomonosov Moscow State University, Russia

Face inversion effect in facial expression recognition in female and male adults was studied applying eye-tracking technology. Forty Russians (19 males and 21 females) and 53 Azerbaijani (26 males and 27 females) participated to the experiment. Photos of two males and two female faces from WSEFEP all displaying seven facial expressions (neutrality, anger, fear, disgust, happiness, surprise, and sadness) were presented randomly each in three conditions: upright, inverted, and Thatcherized. Russian women were slightly more accurate than men in the expression recognition of inverted images; however, there were no significant differences in accuracy decrements caused by inversion and by Thatcherization between male and female participants. At the same time, the two gender groups showed some differences in patterns of eye movements. Women fixated both eyes more frequently compared to men, independently of conditions of presentation. This study was supported by RFBR grant 18-013-01087.

fMRI Evidence That Facial Motion Sensitive Cortex Encodes Relative Feature Timing

Ben Brown, Denis Schluppeck and Alan Johnston
Department of Psychology, University of Nottingham, UK

Face perception reflects the binding of features into a holistic representation, and recent work has reported interactions in the perception of moving features contingent on their relative timing. We asked whether brain areas sensitive to facial motion were modulated by relative feature timing. Nine subjects participated in localiser and phase-encoded functional magnetic resonance imaging experiments. We contrasted silent movies of talking faces with both block-scrambled movies and unscrambled static frames. Voxels significant for both contrasts in the same direction were considered sensitive to facial motion. We then presented a head model whose eyebrows and mouth moved sinusoidally (eyebrows raised/lowered while mouth opened/closed). The mouth moved slightly faster ensuring all eyebrow–mouth timings were presented cyclically. Facial motion-sensitive voxels were modulated more than control voxels at both cycle-rates tested. Facial motion cortex is therefore sensitive to the relative timing of dynamic facial features.

How Does Head Orientation Influence Perceived Gaze Direction From Each of the Two Eyes? Psychophysical Experiments and Analysis of Geometrical Cues in the Stimulus Eye Region

Yumiko Otsuka[1] and Colin Clifford[2]
[1]Department of Humanities and Social Sciences, Ehime University, Japan
[2]School of Psychology, UNSW Sydney, Australia

By using 3 days synthetic face stimulus images with perfectly convergent eyes, we found that the perceived gaze direction was repulsed from head orientation more when only the far eye of the model was visible compared to when only the near eye of the model was visible. Consistent with this, analysis of geometrical properties

of the stimulus eye region revealed a stronger repulsive influence on the far eye than the near eye of the current stimulus images. However, simulation of these effects depended critically on the apparent vergence angle (angle between the pupillary axes between the eyes) of the stimulus. In addition, comparison of our psychophysical data and geometrical characteristics of our stimulus images point to the possibility that the estimation of the iris/pupil position within the eye-opening may be achieved through a process of amodal completion of the whole iris behind the eyelid.

Rapid Categorization of Face-Like Objects in a Fast-Periodic Visual Stimulation

Yuji Nihei, Hiroshi Higashi, Tetsuto Minami and Shigeki Nakauchi
Department of Computer Science and Engineering, Toyohashi University of Technology, Japan

Humans can discriminate face or other objects in a single glance. Moreover, humans also perceives nonface objects as a face. The face categorization performance can be measured as a category-selective response in electroencephalography (EEG)/magnetoencephalography. We considered this category-selective response as generated or modulated by face-likeness. We recorded EEG while presenting natural images of objects at a fast-periodic rate of 12 Hz. We compared neurophysiological responses to periodic and nonperiodic face and face-like object stimuli in a fast-periodic visual stream. We also presented inverted face and face-like object stimuli as a control. As a result, the category (face-like object)-selective EEG responses were elicited from the fast-periodic stream. This result indicates that, as well as face objects, the face-like objects generate a category-selective response in the occipito-temporal cortical areas. Our findings enable a deepening of understanding automatic human perceptual categorization of face.

The Role of Lateralization of Sensory Functions in the Perception of Emotional Expressions in an Asymmetrical Face

Sophie Shirenova, Alexandra Galanina, Alexander Vartanov and Stanislav Kozlovskiy
Department of Psychology, Lomonosov Moscow State University, Russia

Emotions can be perceived differently depending on the asymmetry of face expression, but the role of brain sensory asymmetry of the subject in this process has not been explained yet. Participants: $N = 46$, all right-handed (15 with a left dominant eye and 31 with a right dominant eye), age 23.5 years, standard deviation = 3.8. Stimuli were 37 standardized symmetrical and asymmetrical emotional face expressions. Subjects evaluated the intensity of emotional expression. Subjects with a left dominant eye estimated sadness, disgust, and surprise as less expressed compared to subjects with a right dominant eye. Emotions of happiness, fear, and anger were evaluated equally. Asymmetrical faces with an emotional expression on the left or on the right side rated as two or four conditional points (2|4, 4|2) were perceived as expressing emotions more intensively than a symmetrical face expressing emotion rated as three conditional points (3|3). The study was supported by the Russian Science Foundation (project #16-18-00066).

A Size-Assimilation Illusion Between Facial Parts and Its Dependence on Face Image Size

Kazunori Morikawa, Huiwen Sun and Soyogu Matsushita
School of Human Sciences, Osaka University, Japan

Perception of objects' size is influenced by the size of nearby objects. For simple geometric shapes, this influence usually manifests itself as illusions of size contrast such as the Ebbinghaus illusion (Titchener circles). If the eyes or mouth of a face are rendered larger, does the nose appear smaller due to size-contrast illusion, or larger due to size-assimilation illusion? We examined the effects of eye size and mouth size on perceived size of the nose using psychophysical experiments. Results clearly showed that the larger eyes and mouth make the nose appear larger than it really is, supporting size assimilation. Inverting the faces made the illusion much weaker, indicating that the illusion depends on holistic processing of faces. Moreover, when we varied the face image size, the size-assimilation illusion between facial parts was stronger for smaller face images, suggesting that the illusion is related to goodness of Gestalt-like organization of facial parts.

Age Perception for Human Faces Covered With Global Concentric Pattern

Miyuki G. Kamachi, Yui Sawamura and Meisei Yasuda
Department of Information Design, Faculty of Informatics, Kogakuin University, Japan

Surface information on the skin such as wrinkles is used for judgment of facial age. We hypothesized the spatial frequencies (SFs) used for discrimination may differ in each age-group, since frequency of the sign such as wrinkles may become an important global, not local, feature to detect the person's age. In the series of experiments, facial images from three age groups were used as stimuli with superimposed patterns of global concentric shape, which included various SFs (10–50 cycles/face width). The task for participants was to select a younger face from two successively presented faces. Results on the first glance showed that changing SFs had no effect on perception for any age groups. There was, however, strong tendency for presentation sequence, first face with higher SF was perceived elderly than second one, and inverse results were obtained when higher SF was presented as the second face. We conclude that there is an important age aftereffect on successive presentation of faces.

The Effects of Imagined Intergroup Physical Contact on Race Categorization

Soraya Elizabeth Shamloo, Rosandra Coladonato, Carlo Fantoni and Andrea Carnaghi
Department of Life Sciences, University of Trieste, Italy

We addressed whether imagining touching the hand of a Black individual (i.e., Intergroup Physical Contact; InterPC) compared to imagining touching the hand of a White individual (i.e., Intragroup Physical Contact; IntraPC) affected participants race categorization. After the experimental manipulation, we exposed White participants to 28 morphed faces with different percentages of Black and White traits (i.e., 20%, 40%, 60%, 80%) and asked them to categorize the faces as either White or Black. Results showed that (a) ethnic categorization is influenced by participants' group membership given that faces with equal percentage of Black and White traits tended to be categorized as White and (b) participants' sensitivity to ethnic features depends on the experimental manipulation: It decreases toward outgroup assimilation in the InterPC compared to the IntraPC condition. Results suggest that imagined intergroup physical contact may affect participants' judgement of race.

The Temporal Dynamics of Identity Encoding for Famous Faces

Géza Gergely Ambrus[1], Daniel Kaiser[2], Lisa-Celine Süllwold[1] and Gyula Kovács[1]
[1]Institute of Psychology, Friedrich Schiller University Jena, Germany
[2]Neural Dynamics of Visual Cognition Group, Freie Universität Berlin, Germany

Recognizing individual faces is a challenging task for the visual system. Recently, functional magnetic resonance imaging decoding studies have revealed face identity representations in occipitotemporal cortex. To uncover the temporal emergence of these representations, we used representational similarity analyses and a deep neural network (DNN; VGG-face) to model electroencephalogram (EEG) signals. Participants viewed images of four celebrities while performing an orthogonal task. From around 200 milliseconds, EEG signals contained face identity information. When controlling for early DNN representations (reflecting simple visual features), this information remained intact. Removing intermediate DNN representations delayed identity information to after 400 milliseconds, suggesting a transition to less visually driven representations. Finally, more complex DNN representations fully explained neural identity information. Our results suggest a gradual emergence of identity information and show a striking convergence between identity coding the brain and in a DNN.

A Comparison of the EvoFIT Face Composites Constructed in the Normal Way and When Made Online Without an Administrator

Priscilla Heard[1], Charlie Frowd[2] and Thomas Hewett[1]
[1]Department of Health and Social Sciences, University of the West of England, UK
[2]Department of Psychology, University of Central Lancashire, UK

EvoFIT is a computer program originally devised by Frowd, Hancock, and Bruce for witnesses to produce face composites of perpetrators observed carrying out a crime. A new online version has been made by Frowd, Witness at Home, which eyewitnesses can use to construct a face on their own without a trained administrator, usually a police officer. A target image of one of the 10 characters in Coronation Street was shown to 20 witnesses who were not viewers of the TV soap and then 20 to 28 hours later, they made a single composite of the remembered face either in the normal way or online. Preliminary results collected so far (with composites named by fans of Coronation Street) show a trend with more effecting composites produced from the witness-at-home procedure.

Utilizing Instance Segmentation of Facial Parts in Personal Identification

Hwa Jong Kim[1] and Kyung Jin Cha[2]
[1]Department of Computer Engineering, Kangwon National University, South Korea
[2]Department of Management science, Kangwon National University, South Korea

Recently, image instance segmentation has been significantly advanced to be practically applicable to the process of finding accurate parts of given shapes in images. By using Mask-R-CNN, we were able to find that several facial features such as eyes, eyebrows, ears, hair, and nose can be instantly segmented with high resolution, which can be useful in the face identification. In this paper, we examine the probability of identifying same person whose image has been recorded and is located in a database through the use of security camera in a store or urban surveillance cameras to identify individuals. We also analyzed 1,000 images to train the model and used Mask-R-CNN to segment each part of faces. As a result, from the shape of the mask parts and their structure, we were able to define a feature vector map. We also analyzed the number of face parts that are necessary to distinguish each individual and arrived at the set of facial features that are useful in face identification.

Judgement and Empathy of Other People's Face Expressions: A Psychophysical and fMRI Study

Raimund Kleiser[1], Carola Widmann[1], Denise Potthoff[2], Sibylle Wimmer[1] and Rüdiger Seitz[2]
[1]Neuroradiology Neuromed Campus, Kepler Uniklinikum GmbH Linz, Austria
[2]Department of Neurology, LVR-Klinikum Düsseldorf, Germany

Empathy is a key element in interpersonal relationships, ranging from weak to strong. Many neuropsychiatric disorders are accompanied by impaired recognition of emotions and poor empathic processing. To explore the neural structures involved in these processes, we performed an functional magnetic resonance (fMRI) study on 15 healthy volunteers in a 3T MRI scanner. The emotional stimuli consisted of black and white pictures depicting anger, sadness, happiness, and fear in males and females (Averaged Karolinska Directed Emotional Faces). The accuracy and response times (RT) of emotion recognition and the amount and RT of empathy were measured. Happiness was recognized and empathized more and faster than the other emotions. fMRI revealed a network involving occipital, parietal, and frontal cortical areas. Moreover, strong activity in the amygdala—central neural component in emotion processing—was found. Thus, recognizing and resonating with other people's emotions involve differentiated cortico-subcortical neural circuits.

Brain Activity During the Perception of Female Faces With Use of Cosmetics Measured by Near-Infrared Spectroscopy

Emi Nakato
Department of Health Sciences, Ehime Prefectural University of Health Sciences, Japan

Neuroimaging studies on facial attractiveness have reported that the frontal cortex is involved in the judgement of facial attractiveness. Little is known about the brain activity on facial attractiveness when using cosmetics, although it is well known that cosmetics enhance female facial attractiveness. The present study aimed to investigate using near-infrared spectroscopy whether female faces with cosmetics activated the frontal cortex. Participants were seven male university students. Measurement area was the frontal cortex while passively viewing 10 pictures of unfamiliar female faces with or without cosmetics. Results showed that the haemodynamic response in the frontal cortex increased for faces with cosmetics as compared to those without cosmetics. This suggests that the frontal cortex would be involved in the judgement of attractive female faces when cosmetics are used.

Color Affects Recognition of Emoticon Expression

Katsuaki Sakata[1], Songyang Liao[1] and Galina Paramei[2]
[1]Department of Art, Joshibi University of Art and Design, Japan
[2]Department of Psychology, Liverpool Hope University, UK

Conventionally, emoticons are yellow in online communication. We asked whether variation of color affects the emotion read out from emoticons. In an experiment, we presented Angry, Sad, Neutral, Surprised, and Happy emoticons in Red, Orange, Yellow, Green, Cyan, Blue, Purple, and Gray. Japanese females ($N = 24$) assessed each emoticon on the corresponding affective scales with anchors (e.g., "Not Angry–Angry"). We found that color indeed affected the recognized emotion: Neutral emoticons were appraised as Sad in cool colors but Angry in warm colors. Angry and Surprised emoticons were recognized as such regardless of color; however, their affective value was increased by warm colors. In contrast, expressiveness of Sad emoticons was enhanced by cool colors but dramatically decreased by warm colors; this warm–cool effect was

reversed for Happy emoticons. Our results suggest that congruency of affective meaning between emoticon expression and color augments the conveyed emotional message.

Grouping

Hierarchical Inhibition of Contour Integration With Transcranial Magnetic Stimulation

Hongmei Yan, Weiqiang Chen, Long Qin and Yixuan Zhuo
The Clinical Hospital of Chengdu Brain Science Institute, MOE Key Lab for Neuroinformation, University of Electronic Science and Technology of China, China

Contour integration is a fundamental function of visual perception to generate a coherent representation of visual objects, especially in a complex environment. Recent brain imaging and electrophysiological studies have shown that contour grouping engages intra- and inter-areal interactions among specific cortical layers, and effective connectivity among cortical layers is dynamically adjusted over time. However, the underlying neural process remains largely unclear. In this study, we aim to investigate the hierarchical inhibition of several specific visual cortical areas in contour integration from behavior experimental viewpoint. Transcranial magnetic stimulation was applied to interfere instantaneously with the neural activity of different visual cortex (V1, V2, LOC, and BA20) when subjects were asked to identify whether contours were included or not under four kinds of stimulus conditions. The results showed that visual system shows a hierarchical inhibition of visual contours.

Tell Me What You Are Searching for, and I Will Tell You What You Probably Will See

Mohsen Rafiei[1], Andrey Chetverikov[2], Sabrina Hansmann-Roth[1], David Whitney[3] and Árni Kristjánsson[1]
[1]Department of Psychology, University of Iceland, Iceland
[2]Donders Institute for Brain, Cognition and Behavior, Radboud University, the Netherlands
[3]Department of Psychology, University of California, Berkeley, CA, USA

Implicit ensemble learning research shows how humans can learn and represent the statistical distribution of visual features as a probability distribution (PD). Serial dependence research also has shown how what we have seen before affects our current perception. An unanswered question is whether our perceptual processes can be influenced by recently learned feature PDs. To answer this question, we modified a method introduced by Chetverikov, Campana, and Kristjansson where participants learn the distribution of a set of line orientations. In this study, observers searched for an oddly oriented target among distractors from a certain PD. Then, they had to adjust the orientation of a single bar to match the search target. We analyzed whether the learned PD of distractor orientations influenced the orientation judgments in the matching task. We found no effects of distractor set learning on perceived target orientation but considerable target-to-target serial dependencies.

Illusions

Unravelling the Illusion of Flicker Fusion

Diana Umeton[1], Ghaith Tarawneh[2], Jenny Read[1] and Candy Rowe[1]
[1]Institute of Neuroscience, Newcastle University, UK
[2]Department of Electrical and Electronic Engineering, Newcastle University, UK

Like humans, animals are susceptible to visual illusions, and there is new interest in how animals actively exploit illusions to gain survival advantages. Forty years ago, Pough observed that high-contrast striped snakes, whilst highly visible when stationary, appear to blur into their background whilst moving; he speculated that this 'flicker fusion effect' could enhance animal camouflage. Here, using praying mantids tracking computer-generated prey, we present the first experimental evidence that flicker fusion can confer an effective camouflage defence against real predators. When prey moved slowly, mantids were more likely to detect high-contrast striped prey than grey or background-matching prey. However, when the prey moved fast enough to induce flicker fusion, striped prey became as well camouflaged as grey or background-matching prey. Our results confirm Pough's hypothesis and demonstrate that whether a pattern will be perceived as conspicuous or camouflaged depends on its speed.

The Apparent Elongation of a Disk by Its Rotation as Haptic Phenomenon

Akira Imai[1], Yves Rossetti[2] and Patrice Revol[2]
[1]Institute of Arts, Shinshu University, Japan
[2]Inserm UMR-S 1028, CNRS UMR 5292, ImpAct, Centre de Recherche en Neurosciences de Lyon, Université Lyon 1, France

A coin turned end over end between thumb and forefinger of preferred hand while held it by non-preferred hand feels

longer to the turning hand. This apparent elongation of the disk could be called as "rotating-disk" illusion. The phenomenon involves some illusory mechanisms in both hands. We tested robustness of this illusion in Experiment 1 at first. Eight participants rotated five disks one by one and estimated perceived size of each disk as the same way as Cormack's. The apparent size of disk was growing rapidly for 30 seconds and not to become asymptotic within 60 seconds, suggesting that our results were feasible for those of Cormack. In Experiment 2, we constructed a device which made participant rotate the disk by only either hand. The illusion did not increase by the rotation of preferred-hand but grew gradually by the rotation of non-preferred-hand, suggesting that the holding fingers procedurally used to rotation might have great influences on the illusion.

Motion Illusion in a Specific Direction Caused by Blinking of Color LED Pairs

Kazuhisa Yanaka, Aoto Kurihara and Toshiaki Yamanouchi
Information Media, Kanagawa Institute of Technology, Japan

We found a new motion illusion in which lights appears to be moving toward a specific direction, although the light-emitting diodes (LEDs) are only blinking. Two LEDs of different colors, for example, red and blue, are paired. A long row of LEDs is obtained by repetitively connecting pairs. When the even-numbered pairs blink with a square wave of several Hz and the odd-numbered pairs blink with a square wave of the same frequency but the opposite phase, the motion illusion occurs. This illusion is observed only when the LEDs are blinking under a dark condition. This phenomenon occurs due to the apparent motion caused by the difference in response time among the three types of cones. Since the red light is perceived slightly before the blue light, the light appears to move in the direction from red to blue. Experiments show that the motion direction is from red to blue, red to green, and green to blue. This means that the red cones are the fastest and the blue cones are the slowest.

Depth Cue Is Necessary for the Greenback Illusion

Kempei Shiina
Department of Education, Waseda University, Japan

The greenback illusion is a phenomenon that if we superimpose a straight line perpendicular to a side of three-dimensional (3D)—rotated picture of a banknote, the angle does not appear to make a right angle. A previous study showed that the illusion magnitudes were almost the same if we replace the surface pattern of the note with white mask, which indicate that the surface picture is not essential. It still appears that the more the picture is interpreted as a 3D image, the stronger becomes the illusion, because the white—masked note (a trapezium) can induce depth interpretation and can still serve as a cue for perspective information. A simple way to weaken 3D pictorial cues is to blur the three edges of the original picture. In the experiment, a banknote and a white trapezium with fuzzy borders were used. Because the illusion magnitude reduced with the blur operation, the importance of perspective or depth interpretation for the illusion is suggested.

The Solitaire Illusion Generalises to Large Numerosities and Brief Presentation, but Not to Grouping Based Only on Proximity

Marco Bertamini[1], Martin Guest[2] and Michele Zito[2]
[1]School of Psychology, University of Liverpool, UK
[2]Department of Computer Science, University of Liverpool, UK

The solitaire illusion takes the name from the regular configuration of colour disks in a board game. The elements in the centre appear more numerous. In the original demonstration the outside elements form groups of two or four, thus within the subitising range. We tested configurations in which number of elements were 4 or 9 times larger. We included two of the configurations introduced by Frith and Frith (solitaire and vertical bar). We also tested brief or long presentations, two sets of colours, and a split configuration in which elements were separated spatially. The illusion was not affected by numerosity or colour. Presentation time reduced the illusions for the standard but not for the bar configuration. More importantly, the effect was greatly reduced in the split condition. We conclude that grouping is the key variable, but groups have to be spatially segregated by boundaries (not only as clusters created by proximity) to generate an underestimation effect.

About Specific and General Factors for Visual Illusions

Aline F. Cretenoud[1], Lukasz Grzeczkowski[2], Gregory Francis[3] and Michael H. Herzog[1]
[1]Laboratory of Psychophysics, Brain Mind Institute, Ecole Polytechnique Fédérale de Lausanne, Switzerland
[2]Allgemeine und Experimentelle Psychologie, Department Psychologie, Ludwig-Maximilians-Universität München, Germany
[3]Department of Psychological Sciences, Purdue University, IN, USA

Contrary to studies of audition and cognition, we previously did not find evidence for a general common factor for vision but for many very specific ones. For example, we found strong correlations between 19 versions of the Ebbinghaus illusion, which differed in color, shape, size, or texture ($N = 87$), suggesting a factor specific for the Ebbinghaus illusion. However, the Ebbinghaus illusion correlated very little with other illusions. Here, we tested whether illusion perception is orientation-specific, similar to perceptual learning. We tested five illusions with four different orientations ($N = 20$). While we found almost no interillusory correlations, most intraillusory correlations were significant, that is, susceptibility to an illusion does not seem to depend on its orientation. Contrary to perceptual learning, this finding provides further evidence for illusion-specific factors but not stimulus-specific factors.

Individual Differences in Expectation Based Misperception: Effects of Autistic Traits in a Neurotypical Sample

Kadi Tulver, Jaan Aru and Talis Bachmann
Institute of Penal Law, University of Tartu, Estonia

During perception, our brain generates top-down predictions, which aim to facilitate sensory processing. However, it can also result in misperception or even create the illusion of something in the place of nothing. Dual-task experiments have shown that expectation can misguide subjects to perceive a stimulus that has been removed in some trials. Here, we show that over 90% of subjects reported a subjective experience of the auxiliary task stimulus when it was actually absent. We also found a significant negative correlation between the amount of misperceptions reported and the Autism Spectrum Quotient score—people who scored higher on the questionnaire were less likely to experience illusory objects. Overall, our results demonstrate that (a) misperception of an absent stimulus in a dual task is more common than previously thought and (b) individual differences in top-down effects on perception persist and can be linked to autistic traits.

Relationship Between Amodal Completion and the Slimming Effect of Clothes

Yoshie Kiritani, Akane Kawasaki and Ikjoon Chang
Department of Design, Chiba University, Japan

Apparent slimming effect of clothes is one of the functional effects of amodal completion. Exposed body parts correspond to the local condition of junction area, while the shape of clothes is concerned with the global condition of the body's whole configuration. The purpose of this study was, using illustration stimuli, to gauge which condition may be more important for an apparent slimming effect. In Experiment 1, we examined the effect of a skirt's length and its form. The length of skirt corresponds to the local condition of the body, the legs, because the amount of leg exposure depends on the length of the skirt. As a result, the skirts' shape affected the slimming illusion more than its length. Experiments 2 and 3 revealed that the shape of clothes was important because it could hide the thicker part of body and emphasize the thinner part. A supplemental experiment using geometrical figures also revealed that the apparent slimming effect by clothes possibly occurred only in human.

Developmental Susceptibility to Visuospatial Illusions Across Vision and Haptics

Corinne Holmes, Sarah Cooney and Fiona Newell
Institute of Neuroscience, Trinity College, Ireland

Developmental studies of susceptibility to visuospatial illusions are limited and inconclusive, especially those that contrast perception across multiple sensory modalities. Here, we examined spatial perception using three classic illusions—the Ebbinghaus, Muller-Lyer, and Vertical-Horizontal illusions—in which children explored stimuli in three ways: visual only, haptic only, or bimodal. Specifically, we tested younger (6–8 years) and older children's (9–12 years) ability to discriminate spatial extent in the presence (illusion trials) or absence of illusory contexts (control trials). Results suggest both age groups were susceptible to all three illusions, and when vision was involved, susceptibility to the Ebbinghaus illusion increased with age. For the control trials, visual dominance is consistent with previous reports, suggesting developmental shifts in multisensory integration for small-scale object perception and large-scale spatial navigation.

Once Again About the Origin of the McCollough Effect

Manana Khomeriki[1], David Janelidze[1], Natela Lomashvili[1], Guram Mikaberidze[2], Khatuna Rusadze[3], Reniko Sakandelidze[3] and Archil Kezeli[1]
[1]Department of Vision Physiology, I. Beritashvili Centre of Experimental Biology, Georgia
[2]University of California, Davis, CA, USA
[3]Department of Biology, A. Tsereteli University, Georgia

There still is no consensus in opinion concerning mechanisms of the McCollough effect origin. In series of experiments, we investigated whether it is possible for the McCollough effect to be formed likewise conditioned reflex reactions. McCollough effect was elaborated in 16 subjects by adding differentiating sound stimuli. Although the effect was elaborated in all subjects, in test condition, presentation of sound stimuli had no impact on effect strength, indicating that the principle of McCollough effect formation differs from the mechanisms underlying conditioned reflex reactions. In another series, during the McCollough effect elaboration "deleting" stimuli (mosaic of colored spots) were used. In such conditions, the McCollogh effect was not induced, suggesting that implicated in its origination must be the top-down, bottom-up regulation mechanism operating with the information received from the retina.

The Effect of Inhibition Mechanisms on Susceptibility to the Ponzo Illusion

Hanna Bednarek[1], Magdalena Przedniczek[1], Justyna Olszewska[2] and Jaroslaw Orzechowski[3]
[1]Faculty of Psychology, SWPS University of Social Sciences and Humanities, Poland
[2]Department of Psychology, University of Wisconsin Oshkosh, WI, USA
[3]Institute of Psychology, Jagiellonian University, Poland

The goal of the study was to examine whether efficiency of executive control of working memory functioning: shifting, updating, and inhibition, allows to predict the degree to which one is susceptible to the Ponzo illusion (geometrical, metric illusion). There is no general classification of perceptual illusions; therefore, many researchers follow their owns. Both contrast and assimilation illusions (Ebbinghaus, Ponzo, and Miller-Lyer) are considered as typical metric illusions, whereas Zoellner and Poggendorf are considered orientation illusions. We assumed that the mechanism responsible for inhibition processes would be a predictor of the degree to which participants are susceptible to metric illusions. Forty-three students (33 women) aged 19–32 years ($M = 23.70$, standard deviation $= 4.26$) participated in the study. The cognitive diagnosis was based on the following computer programs. The results showed that a weak mechanism of distractor's inhibition affects susceptibility to the Ponzo illusion.

Pupillometry Obeys Emmert's Law, Which Co-Varies With Autistic Traits in Typical Adults

Chiara Tortelli[1], Marco Turi[2], David Burr[1] and Paola Binda[3]
[1]Department of Neuroscience, Psychology, Pharmacology and Child Health, Università di Firenze, Italy
[2]Fondazione Stella Maris Mediterraneo, Italy
[3]Department of Translational Research on New Technologies in Medicine and Surgery, Università di Pisa, Italy

We measured pupil size in response to a size illusion. A white figurine presented within an illusory three-dimensional corridor appeared larger when shown at the far end of the corridor than when near (Emmert's law). Importantly, figurines at the far end also caused greater pupil constriction than luminance-matched figurines seen close. This well-known illusion depends on combining signals from retinal images with contextual information about depth. Contextual mechanisms are thought to vary across individuals, being weaker in individuals with high autistic traits. Consistent with this theory, we found that in our sample of 50 typical adults, autistic traits (measured by the autistic spectrum quotient) correlated negatively with the magnitude of pupil modulation (Pearson's $r = -.39$, p .05), accounting for about 15% of the variance. This shows that pupil responses provide an accurate objective index of complex perceptual processes, particularly useful for quantifying interindividual differences.

Verbal and Motor Responses to the Müller-Lyer and Ponzo Illusions

Alla Cherniavskaia[1], Valeria Karpinskaia[1] and Vsevolod Lyakhovetskii[2]
[1]Department of Psychology, Saint-Petersburg State University, Russia
[2]Laboratory of Movement Physiology, Pavlov Institute of Physiology, Russian Academy of Sciences, Russia

The Müller-Lyer and Ponzo illusions were studied using four types of response: a verbal response and three types of sensorimotor response. A touch screen was used to record the movements of the right hand while the participants matched the length of the horizontal lines seen in their illusory context: close-loop pointing (memorizing), immediate open-loop pointing (reproduction), and pointing at neutral stimuli after 10 presentations of the illusion (aftereffect). Verbal responses revealed illusory effects for both figures. The pattern of sensorimotor responses was more complex: Both figures showed illusory effects during reproduction but only the Müller-Lyer figure showed an illusory effect during memorizing and only the Ponzo figure produced an aftereffect. The results reveal differences between Müller-Lyer and Ponzo illusions when sensorimotor responses are used, which is inconsistent with the Milner-Goodale hypothesis of two streams for perception. This study was funded by RFBR 16-06-00858.

The Size of Circles Affect Flash-Induced Shape Distortion Illusion

Kenzo Sakurai
Department of Psychology, Tohoku Gakuin University, Japan

Shape distortion illusion can be induced in a short period by alternating a circle and its blurred pattern. One possible account for this illusion is that less curved outputs of adapted curvature detectors produce apparent polygons. To test this possibility, the latencies of the distortion illusion for differently sized circles were measured. Stimuli consisted of black line-drawing circles (diameters: 2°, 3°, 4°, 5°, and 6°) alternating in 2 Hz with their blurred patterns. They were placed on the left/right side of a central fixation cross on a white background. Observers binocularly viewed the stimuli and pressed a response key when they noticed the shape distortion. Results showed that the latency of shape distortion illusion for the 6° diameter circle was longer than those for the smaller circles. This suggests that a large circle consists of less curved lines needs longer time for adaptation to produce this shape distortion illusion.

Café-Wall Like Tilt Illusion Observed in Alternately Arranged Sinusoidal Gradation Color Gratings

Masanori Idesawa
UEC Museum of Communications, The University of Electro-Communications, Japan

Superposition of sinusoidal gradation primary color (R, G, and B) gratings with suitable phase differences (e.g., 0, .2ϕ, and .5ϕ) were arranged alternately in opposite direction with suitable gap lines; the oppositely shifting anomalous motion illusion and the Café-Wall like tilt illusion were perceived. In case of no or wider gap lines and darker or lighter gap lines, the tilt illusion becomes extremely weak. Changing the intensity of primary colors so that the sum of them keeps equal to that of original gratings or producing the gray gradation gratings with the sum intensity of three colors, the same tilt illusion could be observed. Which means that the tilt illusion relying on not the color but the intensity of gratings. In careful observation of the gap lines, twisted-cord like faint fringe was recognized; then, it is expected that the lateral inhibition in retina plays an important role to produce this tilt illusion.

Effects of Type and Spatial Arrangement of Elements on Apparent Sliding Motion

Nobuko Takahashi[1] and Shinji Yukumatsu[2]
[1]Department of Medical Sciences, Aichi Shukutoku University, Japan
[2]Department of Psychology, Chukyo University, Japan

Apparent sliding motion is perceived in the central area of a pattern, surrounded by elements of different orientation, when observers move their eyes. Takahashi and Yukumatsu showed the effects of perceptual grouping on apparent sliding motion in the central area with noise elements. To investigate the roles of orientation and positional relationship of elements in the perception of apparent sliding motion, we manipulated the type and the spatial arrangement of noise elements in the central area and measured magnitude of apparent sliding motion of the target elements as well as the noise elements. The results showed that magnitude of apparent sliding motion of both target elements and noise elements depended on the type and the spatial arrangement of noise elements. From these results, we can suggest some requirements for perceptual grouping in the perception of apparent sliding motion.

Brocken's Phenomenon Arising in Night Fogs on Flat Ground

Likio Sugano
Department of Human Science, Takachiho University, Japan

Brocken's phenomenon, which is observed in foggy mountainous areas, was noted by Silberschlang: The shadow of a stander with sunlight behind her is projected onto the surface of the opposite thick-layered fog and is displayed like a giant. Why is a body perceived as larger than its actual height in this phenomenon? Besides Ross, few previous studies using vision exist. We succeeded in the artificial reproduction of Brocken's phenomenon during a night fog at ground level. The subject, who was standing in front of parallel rays, was projected onto the fog's surface and looked gigantic. We found that the shadow of the participant on the fog surface appeared like a giant, 3 to 4 meters in size, from the 10-m viewpoint while it was almost halved from the 40-m observing point. We also discovered that the large size of the shadow might be due to the projection onto the fog screen at close range, whereas the size was reduced into half on the far distance screen.

Illusory Size Reduction of Elements With Expansion of the Entire Arrangement

Taiichro Uechi[1] and Makoto Ichikawa[2]
[1]Graduate School of Science and Engineering, Chiba University, Japan
[2]Faculty of Humanities, Chiba University, Japan

Perceived size of elementary dots, which form a circular arrangement, reduces with the expansion of the entire arrangement. In order to examine the basis of this illusory size reduction, we manipulated the amount and size of elementary dots as well as size of the entire arrangement in experiments. We found that apparent size of elementary dots decreased as the amount of dots increased and as the entire region expanded. With more than three elementary dots, we found significant interaction between the amount of dots and size of entire arrangement. In addition, extent of the illusory size reduction increased as the size of elementary dots decrease. From these results, we are proposing that this illusory size reduction is caused by both degradation of performance accuracy due to the magnification of receptive field in cortex at peripheral visual field and the size–distance invariant hypothesis, which is introduced by expansion of entire arrangement.

Measuring the Ebbinghaus Illusion in Children and Adults With Two Different Psychophysical Methods

Daniele Zavagno[1], Silvia Calanchi[1], Rossana Actis-Grosso[1] and Olga Daneyko[2]
[1]Department of Psychology, University of Milano-Bicocca, Italy
[2]Department of Psychology, Sociology and Politics, Sheffield Hallam University, UK

The Ebbinghaus illusion was tested in two experiments with three groups of different age: (i) 6-years-old, (ii) 10-years-old and (iii) adults. In Experiment 1, the method of constant stimuli with a paired comparison forced choice paradigm (which target is bigger?) was used. In Experiment 2, paired comparisons with a visual scale matching method (select a match for each target) was used. Four sets of stimuli were created in which targets and inducers could be identical or different in shape and category. Shape and category similarity had a positive effect on the illusion's magnitude in the two experiments only for adults, but the size of the effect measured in Experiment 1 was significantly larger. Both the pattern of results and the magnitudes of the effect measured with the two experiments differed, instead, in the groups of children. Moreover, Experiment 2 showed that the size distortion is due to the targets surrounded by large inducers, while it is virtually null for targets surrounded by small inducers.

An Apparent-Motion Color Illusion

Rob van Lier
Donders Institute for Brain, Cognition and Behaviour, Radboud University, the Netherlands

An illusory color phenomenon is introduced in which a display of unicolored disks alternates with a display in which each of the colored disks splits in two constituent disks. The latter disks have the same size as the original disks, but have different colors (A and B) such that, when transparently superimposed, they induce the color of the original disks. One constituent disk always has the same position as the original disk, whereas the other disk is displaced a small distance, leaving a partial overlap between them. In this way, two versions of alternating displays (freq. 1 Hz) are created; one in which the disk with Color A remains at the original position, while the disk with Color B jumps away—and vice versa. Although the display colors of the two versions are the same, the overall color percepts appear remarkably different under fixation conditions. We discuss the role of afterimages and argue that the color filling-in processes are mediated by possible apparent motion percepts.

Interactions Across Luminance, Contrast, and Orientation Defined Elements in the Ebbinghaus Illusion

Sofia Lavrenteva and Ikuya Murakami
Department of Psychology, The University of Tokyo, Japan

Both first-order (FO) attributes (e.g., luminance) and second-order (SO) attributes (e.g., local contrast and texture variations) can be detected by the human visual system. We attempted to investigate whether both types of attributes contribute to shape perception in the same or different way by using the Ebbinghaus (Titchener) illusion in which a target disk surrounded by smaller inducer disks looks larger than a target disk surrounded by larger inducer disks. The stimuli were defined by luminance (FO attribute), contrast, or orientation (both SO attributes); attributes defining the target and inducers were either the same or different. The illusion occurred in all conditions, which implies attribute-invariant processing of shape. We also found an asymmetry in the illusion strength, such that FO inducers affected an FO target more than SO inducers did but not vice versa; this may reflect different contributions of FO and SO attributes to the quantitative aspect of the illusion.

A Visual Saltation Illusion With Subjective Contours

Hiroyuki Ito
Department of Design, Kyushu University, Japan

When a visual object is flashed twice at the same location on a screen, followed by a third flash at a separate location, the second flash seems to occur at a location between the locations at which the first and the third flashes occurred (visual saltation illusion). I examined whether the illusion occurred for stimuli with subjective contours. We used a Kanizsa-type subjective contour (produced by pacmen) and an Ehrenstein-type subjective disk (produced by radial line segments) as stimuli. In each case, two sets of stationary-inducing elements were continuously presented with spatial separation during each trial. The subjective figure was presented as a white object on black-inducing elements with a white background. The second flash of each subjective figure was perceived to occur midway between the locations of the first and the third flash. The illusion also occurred for other types of second-order figures. The saltation illusion may not depend on luminance-based motion signals.

Perception of Visual Illusions Is Intact in Schizophrenia

Maya Roinishvili[1], Lukasz Grzeczkowski[2], Albulena Shaqiri[2], Mariam Okruashvili[3], Eka Chkonia[4], Andreas Brand[5], Fred W. Mast[6] and Michael H. Herzog[2]
[1]Institute of Cognitive Neurosciences, Free University of Tbilisi, Georgia
[2]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne, Switzerland
[3]Tbilisi Mental Health Center, Georgia
[4]Department of Psychiatry, Tbilisi State Medical University, Georgia
[5]Institute of Psychology and Cognition Research, University of Bremen, Germany
[6]Department of Psychology, University of Bern, Switzerland

There seems to be no common factor for visual perception because performance levels in many visual tasks correlate only weakly with each other. Similar results were found with visual illusions. However, one may expect common visual factors for individuals suffering from pathologies that alter brain functioning, such as schizophrenia. For example, schizophrenia patients who have stronger positive symptoms may show increased illusions magnitudes. We compared the magnitudes of 10 visual illusions of 59 schizophrenia patients and 54 controls. Surprisingly, only 1 of the 10 illusion magnitudes differed significantly between the groups. Correlations between the different illusions were low and mainly non-significant. In addition, correlations with positive and negative symptoms were also very low and non-significant. We suggest that perception of visual illusions is largely intact in schizophrenia

New Adapting Stimuli in Investigation of the McCollough Effect

Elena Yakimova
Laboratory of Physiology of Vision, Pavlov Institute of Physiology, Russian Academy of Sciences, Russia

The McCollough Effect is a color aftereffect in which colorless gratings appear colored contingent on the orientation of the gratings. We used a new type of adapting stimulus—pictures with the black central area and the periphery as "classical" adapting stimuli (red horizontal and green vertical gratings). One adaptation trial lasted 20 seconds, which included presentation of two colored patterns, each for 10 seconds, trials were presented for 4 minutes. During the induction, five subjects were asked to focus on the center of black area. The test stimuli represented black–white picture with horizontal, vertical, and diagonal patterns. When participants were focused on the test stimulus, they did not see any difference between the patterns. But with moving of focus, horizontal and vertical patterns became greenish and pinkish. These findings shed a light on the issue of retinal area specificity in the McCollough Effect. The reported study was funded by RFBR according to the research project n. 18-315-00439.

Increase Amount of Brightness in Comparison of Brightness

Teluhiko Hilano
Information Media, Kanagawa Institute of Technology, Japan

The appearance of a color depends on the colors near it. In two squares with center circles of the same color, the brightness of the circles will appear to differ depending on the brightness of their backgrounds. The brighter the background, the darker its circle appears. In this research, we prepared many printed samples with center circles of varying brightness. The size of the sample is 8 cm, and the diameter of the circle is 5 cm. We showed these samples to subjects and asked them to select a sample whose center circle has the same center brightness as the reference image. The colors of the samples were evaluated in the $L^*a^*b^*$ color space by a colorimeter. The background color and circle brightness in the reference image are 80 and 60, respectively. When the samples' brightness of the background color were 40, approximately 6.6 differences were obtained.

Learning

Adult Cortical Plasticity Peaks After Every Meal

Cecilia Steinwurzel, Silvia Animali, Paola Binda and Maria Concetta Morrone
Department of Translational Research on New Surgical and Medical Technologies, University of Pisa, Italy

Neuro plasticity is maximal in early life, within the so called critical period, and declines with age. Besides age, cortical plasticity also depends on metabolic variables like diet, weight and physical activity. To start investigating these effects on human adult plasticity, we used Monocular Deprivation (MD), a classic paradigm for measuring plasticity in the visual system; 2 hours of MD in human adults dramatically affect the dynamics of binocular rivalry, transiently boosting the deprived eye. We measured MD twice, in a small fasting regime and after a meal (at approximately the same circadian and menstrual phase in 10 female volunteers). Preliminary data indicate that plasticity is stronger after a meal, almost twice the effect in the small fasting regime. This provides evidence for a link between metabolism and neural function not only at the level of cognitive and affective functions but also in the early visual cortex, where the dynamics of binocular rivalry is regulated.

Novel 3D Objects to Study Recognition and Temporal Context

Ehsan Kakaei, Stepan Aleshin and Jochen Braun
Institute of Biology, OVGU Magdeburg – Center for Behavioral Brain Sciences, Germany

Visual object recognition is thought to be facilitated by temporal context. Preparing to study this connection, we create novel three-dimensional objects with characteristic, complex shapes (https://goo.gl/qACZaJ). By combining tensor multiplication of Bezier curves with genetic algorithms, we generate numerous families of objects, with any desired degree of similarity (within families) and dissimilarity (between families), where 'similarity' is the Euclidean distance between object projections. Viewing object sequences composed 90% of objects from six repeating families and 10% of objects from novel families, observers rapidly learn to distinguish between familiar and novel objects, as well as between familiar and novel families of objects. Presenting objects from 15 families in series, we create characteristic temporal contexts in Hamiltonian sequences. After repeated exposure, prediction of sequence continuation shows rapid recognition and slower sequence learning. This study was supported by ESF ABINEP.

Searching for Meaning: Using Pseudoword Cues to Investigate the Formation of New Object-Word-Connections in Virtual Reality

Lisa Voelker, Dejan Draschkow and Melissa L.-H. Vo
Department of Psychology, Goethe University Frankfurt, Germany

When creating memory representations, the given task plays a great role. It has been shown that searching for objects in scenes leads to comparable or better memory representations than explicitly memorizing objects. In this study, we investigated in how far new object-word-representations can be created if the object name is an unknown pseudoword. Therefore, participants were placed in three-dimensional scenes in a virtual reality environment. After the presentation of a pseudoword cue, they either searched for corresponding objects in the scene until they identified the correct object or were led to the highlighted target object and had to memorize it. We could show that searching for objects creates memory representations, even if the object cue is unknown to the subject. As participants did not know what object, they were searching for in first place; this shows that learning new object-word-representations is possible without an explicit connection between word and target.

Reversal Task Learning as a Tool to Comparatively Study Cognition in Birds in Quantitative Ways

Sofija Perovic[1], Sara Letzner[2], Lukas Hahn[2], Aylin Klarer[2], Jonas Rose[2] and Onur Güntürkün[2]
[1]School of Psychology, University of Padua, Italy
[2]Department of Biopsychology, Faculty of Psychology, Institute of Cognitive Neuroscience, Ruhr-University Bochum, Germany

Higher cognitive abilities are usually associated with mammals, but novel studies show that abilities of some avian species are comparable to those of primates. However, there is a great variability between the class of Aves. To quantitatively compare them, we use Serial Reversal Learning Task. An animal has to recognize changes in reward contingencies, inhibit previously learned response, shift its response to previously irrelevant stimulus, and establish new stimulus-reward association. The real strength of this task is in comparative perspective, as it allows us to exclude many confounding variables. Variation in acquisition session depends on many factors, while the reversals include all those factors and the component of behavioral flexibility. The data collected from the pigeons show that they make more errors for the first reversals than for the acquisition. Within first four reversals, the

error becomes asymptotic and on the level of 30% while corvids have the error rate of 25%.

Avian Hatching as a Strategy to Test Context-Specific Habituation

Andrea Dissegna[1], Massimo Turatto[2] and Cinzia Chiandetti[1]
[1]Department of Life Sciences, University of Trieste, Italy
[2]CIMeC – Center for Mind/Brain Sciences, University of Trento, Italy

Whether habituation is a nonassociative or an associative, form of learning may depend on the perception of the context. In precocious avian species, the hatching moment represents a natural condition to investigate this issue. We exploited this possibility by measuring the stops of the wheel-running behavior to two sequences of five bursts white-noise, presented 1 hour apart, in four groups of chicks (*Gallus gallus*) during their second day of life. Critically, the perceived context of the first day of stimulation changed among the conditions: Chicks were stimulated (a) within the egg, (b) in the incubator, (c) within the same running wheel, and (d) chicks were naive. We observed that chicks stimulated before hatching in the egg and after hatching in the incubator habituated to a lesser extent than chicks stimulated always in the same context (i.e., the running wheel) but to a significantly higher degree than that of naive chicks, supporting an associative interpretation of the habituative phenomenon.

Can Task-Irrelevant Statistical Structure Enhance Perceptual Learning?

Gabor Lengyel and Jozsef Fiser
Department of Cognitive Science, Central European University, Hungary

Statistical learning (ability to extract and store new structures) and perceptual learning (improve visual discrimination abilities) traditionally thought to deal with separate tasks at different levels of visual processing. To test this conviction, we investigated whether perceptual learning can be enhanced by the presence of a task-irrelevant statistical structure. We trained two groups ($N = 16$) of observers for 5 days to perform an orientation discrimination task. For one group, the background color of the scene changed across trials according to a fixed sequence, for the other, it changed randomly throughout the training. Overall, the fix group achieved a larger reduction in discrimination thresholds than the random group. Furthermore, there was a marked difference in performance of the two groups with different context. This suggests that task-irrelevant statistical structure during perceptual learning is automatically and implicitly built in the developing internal representation.

Leaning the Complex Is Easier Than Learning the Simple

Kyoko Hine[1], Haruka Konno[1] and Yoshiaki Tsushima[2]
[1]Department of Information Environment, Tokyo Denki University, Japan
[2]Center for Information and Neural Networks, National Institute of Information and Communications Technology, Japan

Previous studies reported that category learning becomes more difficult as the number of features increases. However, it is still unclear whether information integration category learning, in which accuracy is maximized only if understanding the rule that information from two or more features is integrated, becomes more difficult with the increment of the number of features. Here, we conducted the psychophysical experiments: Participants were asked to classify the visual image into two types. The visual image in four-feature group had four distinctive features, on the other hand, the one in six-feature group had six. Although they were not told the categorization rule, they got feedback immediately after their decision (correct or incorrect). As a result, participants in the six-feature group learned the categorization faster than in the four-feature group. In other words, leaning the complex is easier than learning the simple.

Lightness and Brightness

Lightness Contrast and Assimilation: The Interaction of Central and Peripheral Factors

Predrag Nedimović[1] and Sunčica Zdravković[2]
[1]Laboratory for Experimental Psychology, University of Belgrade, Serbia
[2]Laboratory for Experimental Psychology, University of Novi Sad, Serbia

While contrast effects perceived lightness of a surface (target) in the direction away from the reflectance of the neighboring surfaces (inducers), assimilation has an opposite effect. Previous studies showed the importance of both peripheral (e.g., spatial frequency) and central (e.g., depth) factors. However, the separate contributions and interactions of these factors are still unclear. The main purpose of this study was to test the interaction of peripheral (spatial frequency and reflectance difference between target and inducers) and central (depth between target and the inducers) factors. The spatial frequency of the inducers had

three levels, and the reflectance difference was tested on six levels: 2 targets (12% and 28%) × 3 inducers (7%, 20%, and 33%) reflectance levels. The depth was tested on three levels (0, 30, and 60 cm). Results showed that there is a significant interaction between central and peripheral factors, indicating that contrast and assimilation depend on both types of mechanisms.

Behavioural and Event-Related Potential Responses to Lightness Contrast and Assimilation

Naira Taroyan, Stephanie Acaster, Alessandro Soranzo and John Reidy
Department of Psychology, Sheffield Hallam University, UK

Contrast and assimilation show that the colour of a surface depends on surrounding areas. In contrast, a surface is perceived lighter when next to a dark surface, and darker next to a light surface, vice-versa in assimilation. Previous event-related potential (ERP) research showed that the White effect associates with early ERP differences. In this study, participants viewed a grey target with black/white inducers designed to elicit contrast/assimilation, respectively, and indicated whether the target was darker/lighter than an equiluminant comparison. Behavioural performance was more efficient to contrast stimuli with white inducers and to assimilation stimuli with black inducers. Brain activation, indicated by P1 amplitude, was larger to contrast stimuli with black inducers than those with white inducers. Differences in processing contrast/assimilation between stimuli with black and white inducers may reflect differences in the two phenomena.

The Effect of TMS Intensity on Contrast Sensitivity

Danielle Parrott[1], Seth M. Levine[2], Jens Schwarzbach[2] and Lorella Battelli[3]
[1]Center for Mind and Brain Sciences, Italian Institute of Technology, Italy
[2]Department of Psychiatry and Psychotherapy, University of Regensburg, Germany
[3]Center for Neuroscience and Cognitive Systems, University of Trento - Italian Institute of Technology, Italy

The effect of transcranial magnetic stimulation on neuronal populations remains unclear. One theory postulates that stimulation works as a noise inducer under the principle of stochastic resonance. We investigated whether varying stimulation intensity affects graded levels of visual contrast differently. Single pulse stimulation was delivered to V1 while participants performed a two-alternative forced choice orientation discrimination task of Gabor patches at five contrast levels over four stimulation intensities. For low intensities, stimulation enhanced performance selectively at certain contrast levels. Our results suggest performance is dependent on both pulse strength and stimulus signal strength, contradicting previous assertions that stimulation modulates behavior in a linear manner. Overall, our findings challenge dichotomous accounts of stimulation in which high- and low-intensity pulses are confined to their own distinct categories of effects.

Occipital Lobe Involvement in Visual-Evoked Pupil Responses

Marnix Naber[1], Alessio Fracasso[1], Giorgio Porro[2], Joeri van Helden[1], Carlien Roelofzen[1], Douwe Bergsma[3], Mies van Genderen[4] and Serge Dumoulin[1]
[1]Department of Experimental Psychology, Helmholtz Institute, Utrecht University, the Netherlands
[2]Department of Ophthalmology, University Medical Center Utrecht, the Netherlands
[3]Donders Institute for Brain, Cognition, and Behaviour, Radboud University Nijmegen, the Netherlands
[4]Bartimeus Diagnostic Centre for Complex Visual Disorders, the Netherlands

Recent pupillometric studies suggest that the visual cortex is likely involved in modulating visual-evoked pupil responses (VPR). We performed two separate experiments to find evidence for cortical innervation on the VPR. In Experiment 1, we recorded visual-evoked potentials (VEPs) and VPR to natural scenes from 45 healthy participants. Results showed that a considerable amount of individual differences in VPR were linked to differences in early VEP components (100 milliseconds). In Experiment 2, we tested VPR to stimuli that were presented either in the blind or intact visual field of hemianopia patients with exclusive occipital lobe damage. Pupil responses of hemianopia patients were significantly weaker when stimuli were shown in the blind as compared intact visual field. We conclude that, in addition to the well-known subcortical pathway, a cortical pathway, including the occipital lobe, is causally involved in evoking the VPR.

An Upward Surface Appears Darker: An Effect of the Light-From-Above Prior on Lightness Perception

Yuki Kobayashi and Kazunori Morikawa
Department of Human Sciences, Osaka University, Japan

To perceive surface lightness/reflectance precisely, visual system has to discount the effect of illumination from the surface's luminance. Several factors such as the

surrounding area's luminance or luminance gradient affect lightness perception, presumably because they can serve as illumination cues. Here, we tested whether the surface's direction affects perceived lightness, based on the assumption that illumination always comes from above in nature. Participants observed upward or downward surfaces of the same shape on a cathode-ray tube monitor through a stereoscope, without any illumination cues in a dark room. The experiment employed the method of adjustment. The results revealed that the upward surface appears slightly but significantly darker than the downward one. This supports Adams et al.'s results and demonstrates that the surface direction plays a role in lightness perception. The results are discussed in the context of the light-from-above prior.

Perception of Translucency in Sea Paintings

Cristina Spoiala, Huib de Ridder and Maarten Wijntjes
Perceptual Intelligence Lab, TU Delft, the Netherlands

Under typical viewing conditions, humans quickly distinguish between materials – an achievement of the visual system that is poorly understood. Understanding translucent materials is notably difficult. In our study, we considered a more varied-in-shape material, sea water, as depicted by painters. We chose 10 random paintings from the same period showing the same material, as it seems intuitive that all seas look equally translucent. Data were collected from the online platform MTurk. Reconstructing the ordering from pairwise comparisons, two clusters of participants were found. Interestingly, one cluster showed internally consistent (i.e., transitive) judgements, while the other cluster showed relatively random judgements. It suggests that some observers use fixed criteria to judge translucency, while others switched strategy. Results of the consistent cluster are discussed in terms of translucency depicting ingredients, for example, submerged objects, wave geometry, colour gradients, and so on.

Contrast Manipulation to Alter Translucency Perception of Lemons in 17th-Century Paintings

Francesca Di Cicco, Maarten Wijntjes and Sylvia Pont
Perceptual Intelligence Lab, Delft University of Technology, the Netherlands

As contrast varies with translucency, it can serve as a perceptual cue. We tested the effect of contrast manipulation on translucency perception of lemons in 17th-century paintings. Five participants rated lemons' translucency in two experiments, for color images and grayscale versions. The stimuli were the areas of the lemons' pulp segmented from 23 paintings. The luminance histogram of each stimulus was manipulated with a nonlinear function to produce one version of the image with higher and one with lower contrast. For both the color and the grayscale images, in 70% of the cases lowering the contrast increased translucency and vice versa. By regressing the mean and skewness of the luminance histograms, we could partly explain perceived translucency. The ratings for the color and grayscale images were highly correlated ($r = .85$, p .001). So, perceived translucency of the lemons could be altered by the image contrast, and the effects were similar in the color and grayscale conditions.

Material Cues From the Past: Experimentally Testing a Historical Description of Material Rendering

Mitchell van Zuijlen, Francesca Di Cicco, Sylvia Pont and Maarten Wijntjes
Industrial Design Engineering, Delft University of Technology, the Netherlands

In a 17th-century treatise, Beurs described recipes for depicting materials convincingly. Based on these recipes, we defined seven visual cues (e.g., highlight, edge reflection, etc.) needed for a convincing grape depiction. In two experiments, participants were asked to report (a) whether the visual cues were present and (b) to rate perceptual qualities, including convincingness, for painted depictions of grapes. We found no linear relation between the visual cues and convincingness. We did find that four cues predict perceptual qualities, namely, bloom, glossiness, and translucency. The visual cue "highlight placed where there is no bloom" appears to be a significant predictor for both gloss and translucency perception, while the latter is also predicted by "edge reflections." Our finding suggests that painters from this era possessed explicit knowledge about triggers for material depiction that are remarkably similar to midlevel cues explored in contemporary research on material perception.

Task-Dependent and Flexible Mean Brightness Judgment for Achromatic Ensembles

Eiji Kimura[1], Yusuke Takano[1] and Mayu Sekizuka[2]
[1]Department of Psychology, Graduate School of Humanities, Chiba University, Japan
[2]Faculty of Teacher Education, Shumei University, Japan

We investigated how brightness can be averaged for briefly presented heterogeneous achromatic patches using two stimulus arrays composed of different numbers of patches. The results demonstrated precise mean brightness judgments; discrimination thresholds with multiple patches were similar to or even smaller than those with single patches. However, a mild, but consistent, bias was also found favoring some specific items in the display (e.g., the highest luminance patch). Moreover, the direction of the bias flexibly changed with task requirement (choosing either the brighter or darker array) even when the stimulus was completely the same. In contrast, if the task was the same, the bias changed little with changes in apparent contrast caused by presenting the patches on a white, instead of a black, background. These findings implicated flexible weighted averaging; mean brightness can be efficiently judged with flexibly and efficiently relying more on a few items relevant to the task.

Estimating Perceived Transparency Using Conjoint Measurement

Guillermo Aguilar, Minjung Kim and Marianne Maertens
Modelling of Cognitive Processes, Technische Universität Berlin, Germany

Dark transparencies appear more transmissive than lighter ones of the same physical transmittance. This indicates that physical transmittance and the reflectance of the transparent medium are both important for transparency perception. It has been suggested that computations based on Michelson contrast would explain this phenomenon. Perceived transparency has mostly been measured using matching tasks, which do not directly access the internal psychological variable of interest. Here, we use maximum likelihood conjoint measurement (MLCM), which measures the joint effect of physical transmittance and reflectance on perceived transparency. Stimuli were variegated checkerboards. In a two-alternative forced choice task, observers judged which stimulus was more transmissive. We obtained perceptual scales and compared them with predictions based on contrast computations. Empirical and predicted scales are not as consistent as expected. We discuss methodological issues of measuring perceived transparency using MLCM.

Understanding the Reduction in Michelson Contrast for the Perception of Transparency

Minjung Kim, Guillermo Aguilar and Marianne Maertens
Softwaretechnik und Theoretische Informatik, Technische Universität Berlin, Germany

For simple stimuli such as sine waves, perceived transmittance is well-explained by computations based on Michelson contrast. Here, we studied how these findings might generalize to more naturalistic scenes. We simulated checkerboard scenes, sampling reflectances from a uniform distribution. The contrast distribution of these scenes were qualitatively similar to the contrast distribution in natural photographs. Adding a transparency narrowed the distribution, and the narrowing was more severe for lighter transparencies. Thus, transparency perception could be a problem of whether a contrast distribution is more similar to the plain view distribution or one of the transparency distribution. In an experiment, observers matched the perceived transmittance of transparencies with different parameters. Indeed, we found that scenes with matching transparency parameters resulted in similar contrast distributions.

Magnitude, Time and Numerosity

Monotonic Responses to Numerosity in Early Visual Cortex

Jacob Paul, Tuomas ten Cate and Ben Harvey
Department of Experimental Psychology, Helmholtz Institute, Utrecht University, the Netherlands

Humans and many animals have neurons tuned to specific numerosities that decrease in response amplitude with distance from their preferred numerosity. It remains unclear how such tuned responses are derived from visual images. Computational models suggest an initial monotonic stage in early visual cortex where response amplitude increases with numerosity. Here, we utilized the superior spatial resolution of 7T functional magnetic resonance imaging and pRF visual field modeling to characterize the exact location and nature of responses to small (1–7 and 20) visual numerosities. Numerosity explained responses in early visual areas (V1, V2, and V3) better than low-level stimulus features known to covary with numerosity, with explanatory power decreasing up the visual hierarchy. Models of responses to second-order contrast in our stimuli suggest a simple, biologically plausible mechanism linking established low-level response properties of early visual cortex with higher level numerosity-tuned responses and perception.

A SNARC-Like Effect for the Perceived Size of Both Physical and Illusory Figures

Valter Prpic[1], Mauro Murgia[2], Alessandro Soranzo[3] and Tiziano Agostini[2]
[1]Division of Psychology, De Montfort University, UK
[2]Department of Life Sciences, University of Trieste, Italy
[3]Department of Psychology, Sociology and Politics, Sheffield Hallam University, UK

The Spatial-Numerical Association of Response Codes (SNARC) predicts faster left (vs. right) key responses for small (vs. large) numerical magnitudes. A similar effect was demonstrated also for non-numerical magnitudes, such as the physical size of pictorial figures. In the present study, we aimed at investigating whether a SNARC-like effect can be elicited by the perceived size of both physical (real triangles) and illusory (Kanizsa's illusory triangles) figures. Two series of triangles with illusory versus real contours were created, and the size of each figure was manipulated in five progressive versions. Participants performed a two-alternative forced choice task by comparing the perceived size of both illusory and real triangles, in two separate conditions. Results show that small (vs. large) figures are responded faster with a left (vs. right) key in both the conditions, suggesting that a SNARC-like effect can be elicited by the perceived size of both physical and illusory figures.

Spatial but Not Temporal Numerosity Thresholds Correlate With Formal Math Skills in Children

Paula Andrea Maldonado Moscoso[1], Giovanni Anobile[2], Roberto Arrighi[1], Elisa Castaldi[3], Eleonora Grassi[1], Lara Pedonese[1] and David Burr[1]
[1]Department of Neuroscience, Psychology, Pharmacology and Child Health, Università degli studi di Firenze, Italy
[2]Department of Developmental Neuroscience, Stella Maris Scientific Institute, Italy
[3]Cognitive Neuroimaging Unit, CEA DRF/I2BM, INSERM, Université Paris-sud, Université Paris-Saclay, NeuroSpin Center, France

Recent studies have demonstrated that numerosity perception transcends stimuli sensory modality and "format" (sequential or simultaneous presentation). Many experiments suggest that sensitivity to numerosity correlates with performance in symbolic math. Here, we measured precision for estimating the numerosity of both spatial arrays and temporal sequences in children and correlated performance against formal math skills. Sensitivities for estimating temporal numerosity correlated well with those for spatial numerosity. However, while formal math abilities correlated well with both estimation and discrimination numerosity thresholds for visual arrays of dots, they did not correlate with estimation thresholds of numerosity of sequences of flashes or sounds. Taken together, these results support the existence of a generalized number sense and go on to demonstrate an intrinsic link between mathematics and perception of spatial but not temporal numerosity.

Measuring the Numerosity Perceptual Field

Irene Togoli[1], Giovanni Anobile[2], Nicola Domenici[3], David Burr[3] and Roberto Arrighi[3]
[1]Department of Translational Research on New Technologies in Medicines and Surgery, University of Pisa, Italy
[2]Department of Developmental Neuroscience, Stella Maris Scientific Institute, Italy
[3]Department of Neuroscience, Psychology, Pharmacology and Child Health, University of Florence, Italy

Humans and other species have perceptual mechanisms dedicated to estimating approximate quantity: a sense of number. Recent studies have shown that the number sense generalizes across stimuli and also across action and perception, with the number of self-produced movements distorting perceived numerosity of subsequent visual stimuli displayed where the tapping had occurred. Here, we measured the spatial tuning of motor adaptation aftereffects. We measured the magnitude of perceived numerosity distortions for five different distances (0°, 10°, 15°, 20°, and 30°) between the tapping hand and the test stimulus position along the horizontal axis. We found that perceived numerosity was robustly distorted (on average by about 20%) within an area of 10° to 15° centered on the tapping position. Taken together, our results point to the existence a generalized number mechanism integrating the numerosity of perceived stimuli and self-produced actions with a precisely defined spatial tuning.

Local and Global Contextual Effects on Duration Reproduction

Filip Agatić, Chris Mathys and Domenica Bueti
Cognitive Neuroscience, SISSA, Italy

Accuracy of time intervals reproduction from visual cues does not only depend on duration encoding in the human brain but also on the context of visual cues presentation. Motor responses are shaped both by the stimulus duration probability distribution and by recent history effects of preceding responses and observed durations. To assess the influence of these effects on the reproduction

accuracy, we fit a linear model. We used the same five time durations of uninterrupted visual cues in five conditions, differing by probability (20%, 40%, 60%, 80% and 100%) of the central duration (600 milliseconds). We found that the central tendency effect persists independently of the duration probability distribution, and that the attractive effect of the last action response dominates the repulsive effect of the last observation. In Bayesian terms, these findings suggest that the prior expectation of duration is more strongly influenced by recent motor actions than by the duration probability distribution.

Distortions of Perceived Duration of Visual Stimuli Induced by Adaptation to Tapping Movements

Roberto Arrighi[1], Nicola Domenici[1], Giovanni Anobile[2], Irene Togoli[3] and David Burr[1]
[1]Department of Neuroscience, Psychology, Pharmacology and Child Health, University of Florence, Italy
[2]Department of Developmental Neuroscience, Stella Maris Scientific Institute, Italy
[3]Department of Translational Research on New Technologies in Medicine and Surgery, University of Pisa, Italy

We measured motor adaptation of event duration by asking subjects to discriminate the duration of two stimuli (horizontally drifting sinusoidal gratings) successively displayed left and right of screen center. In the adaptation condition, each trial commenced with subjects tapping either rapidly or slowly in mid-air (with hand movement recorded by an infrared device) for 6 seconds in one location (left or right), then performed the duration discrimination task. We found that the tapping action robustly changed perceived duration of stimuli presented to that screen-side, with fast-tapping decreasing duration and slow-tapping increasing it (25%–30% in total). These results reinforce previous work demonstrating interactions between vision and action for numerosity perception and extend them to time perception. Taken together, the work points to the existence of shared neural mechanisms for time, action and number.

Magnitude Affects Temporal Processing in Sub-Second but Not in Supra-Second Time Scale

Anuj Shukla, Rakesh Sengupta and Raju S. Bapi
Cognitive Science Lab, International Institute of Information Technology, India

A Theory of Magnitude (ATOM) suggests that space, time and quantities are processed in the brain through a common mechanism and therefore magnitude biases temporal processing. It is not well established whether such biasing is robust to manipulation of magnitude domains (size vs. number) or magnitude of temporal duration itself (sub-second vs. supra-second). The temporal discrimination (between a target and reference duration) paradigm was used to manipulate Number, Size, Number-Size Congruent and Number-Size Incongruent conditions for sub-second and supra-second time scales. The result of the experiment suggests that time scale (Supra and Sub-Second) and its interaction with magnitude processing are different. The perceptual bias that seems to be in action in the sub-second range is not operative in the supra-second range. The finding shows that the interaction among magnitude, time and numerical processing is more complex than what ATOM theory seems to suggest.

Memory

The Influence of Both Visual Working Memory and Visual Salience on Pre- And Post-Awareness?

Yun Ding, Chris Paffen, Marnix Naber and Stefan Van der Stigchel
Department of Social and Behavioural Sciences, Utrecht University, the Netherlands

We conducted several experiments to explore whether visual working memory and salience can modulate (a) the priority of access to visual awareness and (b) the visual processing in the post-awareness period. With a breaking Continuous Flash Suppression paradigm, we first replicated the finding that both visual working memory (VWM) relevance and visual salience modulate the priority for access to visual awareness. More interestingly, these two effects were numerically additive suggesting that VWM and salience modulate the priority for access to visual awareness simultaneously. Race model analyses revealed that these two effects worked independently. In the monocular condition, we observed the same effects. Our results therefore suggest that VWM and salience can regulate our behavior in both pre-awareness and post-awareness visual processing.

Fast-Backward Replay of Sequentially Memorized Items in Humans

Qiaoli Huang, Jianrong Jia, Qiming Han and Huan Luo
School of Psychological and Cognitive Sciences, Peking University, China

Storing temporal sequences of events is fundamental to many cognitive functions. However, how the sequence order information is maintained and represented in working memory and its behavioral significance, particularly in human subjects, remains unknown. Here, we recorded electroencephalography in combination with a temporal response function method. We demonstrate that serially remembered items are successively reactivated during memory retention with two interesting properties. First, the item-by-item reactivation is compressed within a 200 to 400 milliseconds window, suggesting that external events are associated within a plasticity-relevant window to facilitate memory consolidation. Second, the replay is in a temporally reversed order and is strongly related to the recency effect in behavior. This fast-backward replay, previously revealed in rat hippocampus and demonstrated here in human cortical activities, might constitute a general neural mechanism for sequence memory.

Reward Boosts Visual Working Memory Precision as a Function of Age

Annamária Manga, Pál Vakli, Petra Kovács and Zoltán Vidnyánszky
Brain Imaging Centre, Research Centre for Natural Sciences, Hungarian Academy of Sciences, Hungary

Recent theories conceptualize working memory capacity as the flexible allocation of a limited resource. However, how motivation guides resource allocation and whether it is affected by age remain open questions. Here, we investigated this issue by asking 75 young and 59 elderly individuals to memorize colored lines with different orientations and reproduce the orientation of a cued line as accurately as possible. At the beginning of each trial, a cue indicated whether small or large monetary reward could be earned. We found that participants gave more accurate answers in trials where high monetary reward was anticipated than in the low-reward condition. In addition, our results revealed that this reward effect is significantly reduced in elderly compared to young participants. These findings provide evidence that monetary incentives increase the quality of visual working memory representations as well as for the deterioration of these processes with age.

Involuntarily Attentional Biases by Visual Working Memory: Target–Distractor Similarity of Search-Irrelevant Features Matters

Rebecca M. Foerster and Werner X. Schneider
Neuro-Cognitive Psychology & CITEC, Bielefeld University, Germany

Visual search for varying targets requires maintaining a target template in visual working memory (VWM). Recently, we showed that not only relevant but also search-irrelevant features of a VWM template bias attention in an object-based way. Here, we investigated the role of target–distractor similarity. Participants had to saccade to a target appearing left or right opposite a distractor. The target was defined by a single feature dimension (e.g., shape) indicated by a preceding cue. However, the search cue also varied in another feature dimension (e.g., color), which the distractor shared in half of the trials known by subjects. Matching distractors captured the eyes more often than nonmatching distractors. The magnitude of this attentional bias was modulated by target–distractor similarity in both feature dimensions. Results argue for involuntary and object-based top-down control by VWM templates and effects of target–distractor similarity of all feature dimensions.

Using Your Hands, Which Numbers Did You See? Empirical Evidence on Short-Term Memory Processing of Bilingual German Sign Language Speakers Compared to Bilingual American Sign Language Speakers

Gediminas Schueppenhauer and Katarzyna Stoltmann
Laboratory Phonology (FB I)/Syntax and Lexicon (FB III), Leibniz-Zentrum Allgemeine Sprachwissenschaft, Germany

To keep serially ordered verbal information in short-term memory, hearing speakers primarily rely on phonological coding while deaf signers seem to rely more on spatiotemporal coding. We conducted a video-based digit span task, comparing unimodal German monolinguals and hearing bimodal bilinguals fluent in German and German Sign Language. By manipulating language modality at three processing stages (presentation, shadowing, and recall), we were able to show that spoken shadowing improved the maximum digit span of both groups (main effect: $p = .005$). However, the groups significantly differed from each other during recall ($p = .025$): While monolinguals showed an improved performance during spoken as opposed to signed recall, bilinguals performed equally well in both modalities. This confirms previous findings on English-American Sign Language bilinguals and may imply that bimodal bilinguals rely less on phonological codes, making use of cross-modally integrated information instead.

Categorical Distinction of Real Objects and Location Binding Are Separate Sources of Interference in Visual Working Memory

Yuri Markov and Igor Utochkin
Department of Psychology, National Research University Higher School of Economics, Russia

One of the important sources of failures in visual working memory (VWM) is that individual items can interfere with each other. Here, we tested how two causes of such interference—poor categorical distinctiveness and imperfect feature binding—interact. In three experiments, we showed low and high distinctive objects and tested VWM for objects alone, for locations alone and for object-location conjunctions. We found that low object distinctiveness impairs object recognition and increases the number of object-location binding errors. Also, we dissociated the probabilities that these binding errors are due to recognition impairment or a failure of correct binding. Results show that poor distinctiveness increases binding errors rate only due to lacking recognition but not to binding impairment. Together, our findings suggest that object distinction and object-location binding act upon different components of VWM and are separate sources of interference. This study was funded by RSCF #18-18-00334.

Episodic-Like Memory in Newborn Chicks (*Gallus gallus*)

Maria Loconsole[1], Elena Mascalzoni[1], Jonathan N. Daisley[1], Massimo De Agrò[1], Giorgio Vallortigara[2] and Lucia Regolin[1]
[1]Dipartimento di Psicologia Generale, Università degli Studi di Padova, Italy
[2]Centre for Mind/Brain Sciences, University of Trento, Italy

Episodic memory is defined as subjective consciousness of the self-experience, strictly related to mental time travel (the capability to predict future outcomes by past experiences). The term episodic-like memory refers to the possibility to investigate the memory for what-where-context only on a behavioural level in animal studies. We reared chicks alternately in one of the two cages (blue/yellow) with two stimuli (cross/square) on the two corners. Each chick associated one stimulus with food (what), with its location (where) switched depending on the cage (context). At test, chicks were placed in one cage with the same stimulus on both sides: The time chicks spent in each corner was analysed. Binocular and monocular right-eye chicks succeeded the task (i.e., stayed longer in the corner associated with food in that context), providing evidence of episodic-like memory, whereas monocular left-eye system chicks performed at chance. Other variables affecting these results will be discussed.

Neuro-Enhancement of Visual Working Memory Storage and Manipulation via Transcranial-Direct Current Stimulation

Hrag Pailian[1], Emiliano Santarnecchi[2], Alvaro Pascual-Leone[2] and George Alvarez[1]
[1]Department of Psychology, Harvard University, MA, USA
[2]Department of Neurology, Harvard Medical School, MA, USA

Despite their functional significance, visual working memory (VWM) storage and manipulation are severely limited. We aimed to enhance these abilities by applying transcranial direct current stimulation (tDCS) over the right posterior parietal cortex during a VWM task. Participants were presented with colored circles, which were subsequently occluded. All items either remained stationary (storage) or two items swapped positions (manipulation). Participants subsequently reported the color of a cued item. Relative to sham stimulation, we found that 20 minutes of anodal tDCS (2 mA) had no effect on manipulation ability but improved storage accuracy for individuals with low baseline performance. The magnitude of this enhancement scaled continuously with initial storage capacity ($r = -.76$, $p = .001$). These findings suggest that there may be an absolute capacity limit in VWM storage that cannot be exceeded by neuromodulation, and that storage and manipulation may rely on separate neural substrates.

A Novel Approach to Study Memory Skills in Blind Individuals: The Audio Virtual Reality

Walter Setti[1], Isaac Engel[2], Luigi F. Cuturi[3], Monica Gori[3] and Lorenzo Picinali[2]
[1]Bioengineering, Italian Institute of Technology, Italy
[2]Dyson School Design Engineering, Imperial College London, UK
[3]UVIP, Istituto Italiano di Tecnologia, Italy

The Corsi Block test is a paradigm qualified for the evaluation of serial spatial memory skills. It mostly relies on the visual modality and therefore cannot be performed by blind individuals. We implemented an audio-Corsi test built around three-dimensional (3D) spatial audio technology. The sound stimuli have been arranged in an immersive virtual environment employing the 3D Tune-In Toolkit for delivering high-quality spatialisation through headphones. In this simulation, users are at the centre of the sound scenes and are presented with sequences of sounds of increasing length. In order for the users to validate

sound positions, a custom-made interface has been created with buttons arranged according to the virtual sound positions. The audio-Corsi is being validated as a clinical procedure in order to verify the development of spatial and memory skills for visually impaired and blind individuals, clarifying the influence of the auditory modality on spatial memory processes.

Delayed Perceptual Matching of Features and VSTM Load

Michael Pilling[1] and Doug Barrett[2]
[1]Department of Psychology, Oxford Brookes University, UK
[2]Department of Neuroscience, Psychology and Behaviour, University of Leicester, UK

We look at how perceptual matches are made between currently viewed features and those previously viewed and represented in visual short-term memory (VSTM). Observers saw a memory array (1–4 colours) followed—after a blank interval—by a test array (1–4 colours). Observers had to report quickly and accurately if there was a feature match or not. An EZ-diffusion model was used to analyse response data. Observers were similarly efficient at matching colours irrespective of test set-size when they had a single feature held in VSTM but not when they had two or more. With two or more VSTM features, this test set size cost was found irrespective of memory presentation (simultaneous/sequential), order position, or the use of valid cueing. We explain this effect in terms of ballistic processing of irrelevant viewed information and the requirement, with multiple features, to inhibit during a serial matching process.

Memorization and Visualization in the Visual Cortex and Beyond

Lora Likova[1] and Christopher Tyler[2]
[1]Likova Lab, Smith-Kettlewell Eye Research Institute, CA, USA
[2]Brain Imaging Center, Smith-Kettlewell Eye Research Institute, CA, USA

To analyze the mechanisms of visual working memory, we asked which brain areas are involved in the process of direct visualization from immediate memory storage of previously unfamiliar material. FMRI was run while line drawings were alternately (a) viewed and (b) visualized in a novel procedure to enhance their memory representations. Remarkably, viewing and visualization equally activated mid- and far-periphery of primary visual cortex V1, whereas the visualization signal in the parafovea dropped to about half of that of the direct viewing, and then surprisingly inverted into strong suppression within the foveal confluence. A distributed visualization network stemming from peripheral V1 included parietal and frontal regions; conversely, the visual hierarchy beyond V1 was not involved. Granger causality analysis was used to disentangle the interregional interactions and provide deeper insights into the network for visualization from memory.

From Icons to Categories: The Format of Visual Memory Representations Is Task Dependent

Beatrix Keweloh, Sven Ohl and Martin Rolfs
Rolfslab, Bernstein Center for Computational Neuroscience, Humboldt University at Berlin, Germany

Visual memory is routinely probed by either continuous or discrete reports (e.g., rotating a knob vs pressing one of the two keys) which may favor a different memory format. We developed a new double-cueing paradigm to manipulate and assess the format of visual memory representations within a single trial. More specifically, we asked participants to report the orientation of one of the two randomly oriented Gabors in either a continuous or discrete response mode as indicated by a precue presented before memory array onset. Critically, the precue could be valid, invalid, or neutral as revealed by a retro-cue that was always valid and presented during memory maintenance. Participants clearly encoded memory representations in the precued format: Even for a set size as low as two, we observed large costs and strong biases when items were encoded in a discrete fashion but then had to be reported on a continuous scale.

The Influence of Expertise on Continuous Categories: A Whole Report Study of Colour Expertise

Jonas Olsen Dall and Thomas Alrik Sørensen
Department of Communication and Psychology, Aalborg University, Denmark

Recently research has shifted from examining discrete categories (e.g., letters) to continuous categories (e.g., colours). While studies have shown that stimuli-specific expertise influence discrete categories, there are little research into how it influences continuous categories. The current study comprises of a whole report experiment with two conditions: discrete and continuous. We divided participants into two groups based on the degree of colour expertise: normal colour expertise and colour experts. By varying stimulus exposure durations, we can fit data using the TVA in order to isolate specific components of attention like visual short-term memory capacity (*K*), speed of processing (*C*) and the threshold of perception

($t0$). Results reveal no significant group differences in the discrete letter condition, but that colour expertise improve K in the continuous category, leaving C and $t0$ unaffected, indicating that continuous categories improve from expertise similar to discrete.

Experience-Based Knowledge Enhances Accuracy of Metacognition in Patients With Schizophrenia

Ewelina Cichoń and Remigiusz Szczepanowski
Faculty of Psychology in Wroclaw, SWPS University of Social Sciences and Humanities, Poland

The study examined accuracy of metacognition in self-monitoring performance in schizophrenia. We expected that patients' self-monitoring ability will be affected by types of meta-knowledge. Schizophrenic patients ($n = 39$) and healthy subjects ($n = 50$) performed an action memory task in which actions were required to be performed or imagined. Then, participants rated their confidence with post-decision wagering (PDW) and confidence rating. Patients made more errors in recognition of imagined actions as performed and also displayed higher inaccuracy of meta-knowledge. Although when experience-based knowledge (PDW) used, accuracy of metacognition had increased in both groups. Our results confirm recent studies that patients with schizophrenia keep their faulty beliefs with strong conviction that their memories are true, but some aspects of metacognition are preserved. Our findings are also important for the development of therapeutic interventions treating cognitive bias in schizophrenia.

Motion

The Motion Aftereffect Without Motion: How Adaptation to Non-Directional Flicker Creates a Directional Aftereffect in the Motion System

Mark Georgeson[1], George Mather[2] and Robert Lee[2]
[1]School of Life and Health Sciences, Aston University, UK
[2]School of Psychology, University of Lincoln, UK

We describe an unusual motion aftereffect that probes early stages of motion coding psychophysically. Adapting contrast flickers in sawtooth fashion over time, but neither the adapting nor the test grating actually moves. This compelling aftereffect, unlike the classic one, reverses direction when test contrast is inverted. Its strength, measured by nulling, is nearly proportional to adapting contrast and is a bandpass function of adapting flicker rate, peaking at 4 Hz. Standard motion models combine non-directional input filters that encode spatial and temporal gradients of the input image. In our modified model, these input filters also adapt and evoke negative afterimages that represent illusory temporal gradients. Those combine with spatial gradients of the test image to form illusory motion signals. Complex two-dimensional and three-dimensional illusory motions can be evoked, but the site of adaptation is probably retinal or lateral geniculate nucleus cells that sense the way local image brightness varies over space and time.

Neural Mechanisms Underlying Short- and Long-Term Forms of Plasticity Probed With a Motion-Adaptation Paradigm

Sibel Akyuz[1], Andrea Pavan[2] and Hulusi Kafaligonul[3]
[1]Department of Psychology, Osmaniye Korkut Ata University, Turkey
[2]School of Psychology, University of Lincoln, UK
[3]National Magnetic Resonance Research Center (UMRAM), Bilkent University, Turkey

Neural adaptation can establish over very short timescales, but the neural mechanisms underlying such rapid form of neural plasticity are still debated. Here, short- and long-term forms of neural plasticity were investigated using a motion adaptation paradigm combined with electroencephalography. Participants were adapted to directional gratings for either 0.640 seconds or 6.4 seconds. Both adaptation durations led to motion aftereffects, but long adaptations produced stronger motion aftereffects. In line with behavioral results, we found robust changes in the event-related potentials elicited by the test pattern within 50 to 110 milliseconds time range over occipital and parieto-occipital sites. Within this time range, the aftereffects induced by long-term adaptation were stronger when compared to those induced by short-term adaptation. Taken together, our findings provide evidence for changes in the spatiotemporal profile of the neural activity underlying short- and long-term forms of neural plasticity. This study was supported by British Academy Newton Mobility Grant.

Dissecting Long-Range Motion

Marlene Poncet and Justin Ales
School of Psychology and Neuroscience, University of St Andrews, UK

When two objects are presented in alternation at two locations, they are seen as a single object moving from one location to the other. This long-range motion percept suggests that the brain integrates information over long distances. However, no current models can explain how it can be possible. This study investigates the neural markers of long-range motion by parcelling out the contribution of spatial and temporal interactions in short- and long-range motion. Participants' electroencephalography was recorded while they viewed two stimuli in apparent motion. The same stimuli were presented without inducing motion either simultaneously, to test for spatial interaction, or at double the temporal frequency in only one location, to test for temporal interaction. In all conditions, we observe an inhibition of the evoked response compared to a linear prediction. This inhibition was particularly strong for temporal interactions, approaching the magnitude of the inhibition observed for a moving stimulus.

Pattern Motion Responses in Rat Visual Cortex

Giulio Matteucci[1], Rosilari Bellacosa Marotti[1], Benedetta Zattera[2] and Davide Zoccolan[1]
[1]Cognitive Neuroscience, SISSA, Italy
[2]CIMeC, University of Trento, Italy

A crucial step of visual motion perception is the extraction of global direction by integrating local aperture-limited signals. Studies on primates discovered both neurons capable of integration ("pattern cells") and neurons signalling local direction only ("component cells"). Rodents are now emerging as useful model of visual functions, displaying many similarities with primates. By performing single-unit recordings in V1 and two putative-dorsal extrastriate areas (LM and RL), we aim to establish rats as a new model for motion integration. We did so by classifying neurons as "pattern" or "component" depending on their grating and plaid responses. We found pattern cells in all the three areas, V1 included. We also characterized neuronal receptive fields via reverse correlation using the estimated linear filters to predict direction tuning. This could shed light over the computational mechanism behind the "early-stage" pattern selectivity observed in rodents.

Visualising the Illusory Moving Spot in Apparent Motion

William Simpson
Department of Psychology, University of Plymouth, UK

If a spot in one position is flashed on a screen, and then another spot is flashed some distance away, people see a single spot moving in 'apparent motion'. One idea is that the visual system interpolates and 'sees' the spot in positions between the actual flashed locations. We could visualise such interpolation using classification images. Stimuli were three-frame noisy sequences that either contained a spot in Frames 1 and 3, or did not; Frame 2 was always blank. The contrast of the spots was near detection threshold; 3,000 trials were used. The spot shifted position from Frame 1 to Frame 3 in the 'moving' condition. The classification images did not contain a spot in Frame 2 positioned between the spot in Frames 1 and 3. In a control 'static' condition, the spot was not displaced, and an interpolated spot was shown in the Frame 2 classification images. We find no support for the apparent motion interpolation idea, although our classification images would find it if present.

The Neural Mechanisms Underlying High-Frequency Transcranial Random Noise Stimulation: An EEG Investigation

Filippo Ghin, Louise O'Hare and Andrea Pavan
School of Psychology, University of Lincoln, UK

High-frequency transcranial random noise stimulation (hf-tRNS) is a noninvasive electrical brain stimulation technique characterized by alternating current delivered at random frequencies in the range 100 to 600 Hz. hf-tRNS has been demonstrated to increase neural excitability and behavioral performance, but the underlying neural mechanisms are still debated. The aim of this study was to investigate whether hf-tRNS modulates visual evoked potentials (VEPs). Participants ($N = 7$) performed a two interval forced-choice motion direction discrimination task. In separate sessions, either hf-tRNS or Sham control stimulation at 1.5 mA was delivered bilaterally over the MTh+ area. Electroencephalography (EEG) was recorded before and immediately after the stimulation sessions. Preliminary results indicate a difference in VEP amplitude in the occipital cortex approximately 200 milliseconds after the stimulus onset between pre and post hf-tRNS, suggesting the involvement of N1 and P2 components.

Motion and Form: Are Interactions Real or Simply Reflecting Underlying Motion Mechanisms?

Linda Bowns
Cambridge Computational Biology Institute, DAMTP, CMS, Cambridge University, UK

Interactions between form and motion processing have been investigated using glass patterns. These are pairs of

random pixels aligned along an orientation, giving the impression of form. A random dynamic glass pattern is a multiframed glass pattern, where each frame shares form but not motion coherence across frames. Humans perceive motion in these patterns that suggests interaction between the form and motion pathways. The Component Level Feature Model (CLFM) of motion processing was used to examine the possibility that motion could be computed in these patterns. This unique model has the potential for static information to influence perceived/computed velocity without processing form. In simulations, 59% of 800 patterns were processed by CLFM as having a motion direction within $\pm$ 1 of the orientation of the form. It is concluded that human motion mechanisms are not sufficiently understood to rule out their role in "apparent" interactions between the motion and form pathways.

Investigating the Relationship Between Different Optic Flow Parsing Metrics

Lucy Evans[1], Rebecca A. Champion[1], Simon Rushton[2] and Paul Warren[1]
[1]Division of Neuroscience and Experimental Psychology, University of Manchester, UK
[2]School of Psychology, University of Cardiff, UK

Flow parsing (FP) aids detection of scene-relative object movement by filtering retinal motion due to self-movement. Previous work has measured FP performance using different methods. Here, we look for associations between FP metrics obtained under two such methods. Task 1: Participants reported perceived movement of a probe in a two-dimensional radial flow field. Metric 1 is the difference between perceived and actual paths due to global filtering of optic flow under FP. Task 2: The same participants reported perceived movement of a probe in a field of three-dimensional background objects. We recovered direction discrimination thresholds for (a) no observer movement and (b) simulated observer movement. Under FP, performance should be preserved in Condition 2 and change in threshold is taken as Metric 2. We found little evidence for a correlation between FP metrics, suggesting they reflect different aspects of performance. We discuss the relative advantages of different FP metrics in the context of these data.

A Motion Sensing Computational Model for the Inhibitory Mechanism Between Coarse and Fine Scales Reproduces the Observed Speed Tuning Function

Raúl Luna del Valle and Ignacio Serrano-Pedraza
Department of Experimental Psychology, Complutense University of Madrid, Spain
Newcastle University, UK

Motion discrimination is impaired when a static coarse-scale pattern is added to a moving fine-scale pattern and also when coarse and fine scale patterns move together at the same speed. This phenomenon has been explained though the interaction between motions sensors tuned to coarse and fine scales. In the present study, we run a motion direction discrimination experiment where stimuli drifted at different speeds (0.5, 1, 2, 4 and 8 deg/s). The stimuli could be simple (coarse and fine scales of 1 and 3 c/deg, respectively, drifting in isolation) or complex (both simple components added together, with all possible permutations of static versus drifting). Our results reveal a bandpass tuning function for the inhibitory mechanism with a maximum between 2 and 4 deg/s. Using a computational model of motion sensing that includes a stage where the outputs of motion sensors tuned to coarse and fine-scales are subtracted from one another, we reproduce most of our psychophysical results.

The Effect of Semantic Meaning on Speed

Luca Battaglini and Giovanna Mioni
Department of General Psychology, University of Padova, Italy

Every stimulus we perceive is subjected to a semantic analysis. For example, to express the concept of weight is possible to use a feather to recall the idea of lightness or to use a stone to recall the idea of heaviness. Here, it was investigated whether semantic meaning can alter the motion speed perception. Participants were asked to indicate which one between a fast-expected and a slow-expected object was moving faster in a two-interval forced choice task. The stimuli used were a motorbike and a bike (Experiment 1), a hot-air balloon and a rocket (Experiment 2), and a formula one and a tank (Experiment 3). Psychometric function were obtained by fitting the proportion of slow-expected object seen as faster for each level of delta speed. Results showed that the point of subjective equality is significantly lower than zero (delta speed), indicating that when the two objects had similar speed participants see the slow-expected object as moving faster contrary to expectations.

Psychophysical Dissecting Central From Peripheral Vision

Anna Kozak[1], Michal Wieteska[2] and Kalina Burnat-Kuijpers[1]
[1]Neuroplasticity, Nencki Institute of Experimental Biology, Polish Academy of Sciences, Poland
[2]Department of Nuclear and Medical Electronics, Institute of Radioelectronics and Multimedia Technology, Warsaw University of Technology, Poland

We measure acuity using shapes defined by random-dot kinematograms (RDKs). Shapes used in this study had the same surface area but different size. Such stimuli were originally described by Efron to diagnose visual agnosia. The S+ was a circle and S− was an ellipse, displayed simultaneously with randomized left/right position. Two luminance sets of RDKs were tested: black dots on white background, Bcg, or reverse. S± were built from the RDK placed on the Bcg differing from the S± in one of the motion cues: coherence, direction, or velocity. The staircase procedure was used for aspect ratio of ellipse size, varying from 0.2 to 1. Task was more difficult when motion signal was carried by black dots. So, we propose to measure simultaneously central and peripheral vision, as fast assessment of vision is beneficial for patients, for example, after central retinal loss, as we showed recently, also the peripheral motion processing is affected.

Optic Flow Parsing in Schizophrenia

Paul Warren[1] and Alvaro Cavieres[2]
[1]Division of Neuroscience and Experimental Psychology, University of Manchester, UK
[2]Department of Psychiatry, Valparaiso University, IN, USA

Schizophrenia is often accompanied by changes in both local and global motion perception. We might, therefore, expect changes in optic flow parsing (FP) performance, that is, the ability to subtract global retinal flow due to self-movement in order to facilitate assessment of scene-relative object movement. Here, we measured FP in 20 Schizophrenic (Sz) and 20 control participants. Stationary participants viewed a moving probe in one hemifield together with an expanding radial flow field of limited lifetime dots in the same, opposite, or both hemifields and then set the orientation of a gauge to match perceived probe trajectory. FP leads to a deflection in probe trajectory due to global flow subtraction. Although the deflection was similar in Sz and control groups, there was evidence for intergroup differences in the contribution of local and global motion processing mechanisms to the observed effects. We discuss these findings in the context of research on altered motion perception in Sz.

Temporal Process of Vection Occurrence: Experimental Phenomenological Analysis of Verbal Reports

Hidemi Komatsu[1], Kayoko Murata[2] and Takeharu Seno[3]
[1]Faculty of Business and Commerce, Keio University, Japan
[2]Department of Human Science, Tokyo Metropolitan University, Japan
[3]Faculty of Design, Institute for Advanced Study, Kyusyu University, Japan

When stationary observers view an optical flow pattern, they perceive self-motion (vection). An expanding flow pattern is a simulation of forward motion and a contracting pattern is that of backward motion. Temporal properties of vection (latency and duration) have been mainly adopted as quantitative indexes. This study investigated the phenomenological aspects of vection in detail. While 13 observers viewed the expanding or contracting flow pattern and reported orally what they perceived. As a results, it clarified that there was a temporal pattern in the occurrence of vection. At first, they perceived optical flow as objects, then they felt their body motion, and furthermore perceived in detail. And vection begun gradually. Also, although the contracting pattern is a simulation of the backward motion, the backward motion is not always perceived. Whatever quantitative indexes are adopted, there is possible to lead a wrong conclusion unless it is associated with what actually is perceived.

The Influence of Color Change on Judgments of Motion Direction

Tadayuki Tayama and Kei Shiratori
Department of Psychology, Hokkaido University, Japan

It has been known that perceptual speed of moving random dots was decreased by color changes of dots. This indicates silencing motion signal. The present study examined this effect, that is, the influence of color change in random-dot pattern on judgments of motion direction. Dynamic random dots appeared in the circular frame, and the color of each dot changed individually or all dots changed holistically. In a trial, 200 dots were presented, 100 dots of them moved rightward or leftward, and 100 dots changed positions randomly as noise. The ratio of rightward to leftward dots was fixed at the constant. Observers asked to choose the dominant direction between right and left. There were five conditions concerning color changes. The results showed that the ratios of correct response in color-change conditions were lower than that in control condition and that there was no effect of color-change rate on judgments. These results might be explained by perceptual planes formed by moving dots.

Effect of Inter-Stimulus Interval on the Reduction in Vection Latency Caused by Pre-Presented Motion Stimuli

Jing Ni[1], Hiroyuki Ito[1] and Masaki Ogawa[2]
[1]Graduate School of Design, Kyushu University, Japan
[2]Department of Information Engineering, Mie University, Japan

In this study, we examined factors that influence the latency of vection. As a first stimulus, we presented static random dots (control condition) or a vection-inducing stimulus moving vertically (vection-inducing stimulus condition). These were followed by an inter-stimulus interval (ISI) of 0 to 4,000 milliseconds and then a second stimulus presentation. The second stimulus was a vection-inducing stimulus that moved horizontally. We measured the vection latency for the second stimulus. We found that the vection-inducing stimulus condition elicited a shorter vection latency for a second vection-inducing stimulus than the control condition. This difference decreased as the ISI increased. The results indicate that while pre-activation of the visual motion processing system by the first vection-inducing stimulus contributed to visual dominance over the vestibular system at the subsequent presentation of the second stimulus, the dominance disappeared when the pre-activation ceased due to a long ISI.

Contributions of Intuitive Physics and Visual Impressions of Launching to Causal Reports

Michele Vicovaro
Department of General Psychology, University of Padova, Italy

Everyday causal reports appear to be based on a blend of perceptual and cognitive processes. Causality can be perceived automatically through low-level visual processing of stimuli, but it can also be inferred on the basis of an intuitive understanding of the physical mechanism that underlies an observable event. We investigated how visual impressions of launching and the intuitive physics of collisions contribute to the formation of explicit causal responses. In Experiment 1, participants observed collisions between realistic objects differing in apparent material and hence implied mass, whereas in Experiment 2, participants observed collisions between abstract, non-material objects. Results suggest that stimulus factors and experimental design factors – such as the realism of the stimuli and the variation in the implied mass of the colliding objects – may determine the relative contributions of perceptual and post-perceptual cognitive processes to explicit causal responses.

When Perception From Two Eyes Is Slower Than From One Eye: Reduced Surround Suppression in Monocular Motion Perception

Sandra Arranz-Paraíso[1], Jenny Read[2] and Ignacio Serrano-Pedraza[1]
[1]Faculty of Psychology, Complutense University of Madrid, Spain
[2]Institute of Neuroscience, Newcastle University, UK

Paradoxically, duration thresholds for motion discrimination in high-contrast stimuli are longer for large stimuli than for small ones. We examined how this "surround suppression" varies under binocular versus monocular viewing. We obtained duration thresholds for 20 subjects for small (1°) and large (7°) drifting gratings of 1 cpd with 85% contrast. The results did not depend on whether the other eye saw a blank screen or was patched. Averaging across subjects, eyes and techniques, monocular duration thresholds were 29.72 milliseconds for the small stimulus and 40.11 milliseconds for the large one. Surround suppression is thus present but weak. Binocular duration thresholds were significantly lower for the small stimulus (26.1 milliseconds) and longer for the large stimulus (48.18 milliseconds). Thus, surround suppression is reduced with monocular viewing. For small stimuli, people discriminate motion faster with two eyes than with one, but for a large stimulus two eyes are actually slower.

Michotte's Effect in Praying Mantis (*Hierodula membranacea*)

Federica Dal Cin[1], Massimo De Agrò[1], Lucia Regolin[1] and Enzo Moretto[2]
[1]Department of General Psychology, University of Padua, Italy
[2]Butterfly Arc Ltd., Padua, Italy

Praying mantises are sit-and-wait predators. They rely mainly on vision to recognize preys on the basis of key features (e.g., size, contrast, etc.). Motion information may also be crucial. Our aim was to assess whether mantises confronted with video animations of the Michotte's effect respond differentially to the objects depending on their role in the causal event. Twelve insects were presented with an animation depicting two dots. One dot moved until it contacted the second, which started moving thereafter. Mantises at first attacked either dot with the same rate but with successive presentations they preferentially struck the first dot. The same mantises did not exhibit any preference when presented with controls (a "gap plus delay" and an "inverted sequence" animation) in which there was no contact between the dots, ruling out explanations based on preference for the first moving object. Results provide preliminary evidence on the perception of animacy/agency by praying mantises.

The Anti-Barberpole Illusion on the Slanted Surface

Hiroshi Ashida and Mika Hattori
Graduate School of Letters, Kyoto University, Japan

The motion direction of a drifting one-dimensional grating is ambiguous when observed through an aperture, and the perceived direction largely depends on the aperture shape (known as the barberpole illusion). For a grating oriented 45° in a square aperture, we might perceive motion in oblique, horizontal, or vertical directions, and despite large individual differences, there is no general bias in either the horizontal or the vertical direction. We found that, however, when the whole stimulus pattern is slanted by 60° such that the top edge is farther than the bottom, we see motion more likely as vertical, that is, coming toward or going away from us. Similar effect was found with virtual (binocular disparity) or physical slant of the display. This effect opposes the traditional barberpole illusion because the retinal images are squashed vertically so that the horizontal edges become longer than the vertical ones. It might reflect an innate bias in perceiving optical flow in three dimension.

Event-Related Brain Potentials During Peripheral and Central Visual Field Stimulation Generating Self-Motion (Vection)

Behrang Keshavarz[1] and Stefan Berti[2]
[1]iDAPT, Toronto Rehabilitation Institute – UHN, Canada
[2]Department of Clinical Psychology and Neuropsychology, Johannes Gutenberg-University Mainz, Germany

Human event-related brain potentials (ERPs) were measured to identify the sensory processes underlying visually induced self-motion (vection). Participants were shown alternating black-and-white vertical bars that moved horizontally and induced vection when presented for a longer duration. The stimulus consisted of a central and peripheral visual area that moved independently from each other, resulting in four conditions: (a) peripheral and central stimulus moving in same or (b) opposite directions, (c) central stimulus moving with periphery stationary, or (d) vice versa. Vection intensity and duration were verbally recorded and varied between conditions (weakest/shortest with center moving/periphery stationary). Stimulus onset elicited ERPs with parieto-occipital P2 and N2 components. ERP amplitudes varied across conditions but did not fully match subjective vection ratings. We argue that ERPs may reflect early sensory processes contributing to the subjective perception of vection.

The Temporal Characteristics of Attentive Tracking With Dichoptic Stimulation

Hidetoshi Kanaya[1], Marie Morita[2] and Takao Sato[1]
[1]College of Comprehensive Psychology, Ritsumeikan University, Japan
[2]Graduate School of Letters, Ritsumeikan University, Japan

To evaluate the role of first-order motion in attentive tracking, we examined the upper temporal limit for attentive tracking when the stimulus was presented dichoptically. It is well accepted that first-order motion is not perceived from dichoptic presentations. A two-frame ambiguous apparent motion stimulus comprised of four rectangles arranged in square shape in one frame, and diamond shape in the other was presented either binocularly, monocularly, or dichoptically using a stereoscope. The alternation rate was varied between 2.78 and 5 Hz. The observer was asked to track a target object for 1.8 seconds. It was found that the limit was 4 to 5 Hz for all viewing conditions. These limits are similar to that for simple first-order apparent motion and much higher than the limit (2–3 Hz) for voluntary shifts of attention. These results suggest that certain low-level motion contributes to attentive tracking, but the motion is not the prototypical first-order motion.

Speed Overestimation in Chasing Events

Giulia Parovel and Stefano Guidi
Department of Social, Political and Cognitive Sciences, University of Siena, Italy

Many studies show an association between speed and animacy: Objects moving faster tend to be judged as more animated. We explored the effect of different contexts on speed perception of objects with different degrees of animacy. Paired comparisons were used to compare the perceived speed of a square moving on the screen alone or in the context of a second square. The context element was either static or moved showing an animate-like or a physical-like trajectory, and the target moved toward it or away from it, always at the same physical speed. Results showed that the target perceived speed was greater in some of the contexts in which it was seen as more alive. The effect, however, was only significant when the target was moving away from the context square, and the context square showed an animate-like trajectory, suggesting a specific association between speed and chasing but not between speed and animacy tout court.

The Effect of Translational Directions in 3D Real Space on Vection

Kayoko Murata[1], Yoshitake Fujii[2], Kousuke Tokunaga[3] and Takeharu Seno[3]
[1]Department of Human Sciences, Tokyo Metropolitan University, Japan
[2]Research Organization of OIC, Ritsumeikan University, Japan
[3]Faculty of Design, Institute for Advanced Study, Kyushu University, Japan

Sato et al. reported that when the optical flow was presented on the ceiling or the floor side for observers and vection strength was measured, stronger vection was perceived on the floor side than the ceiling side. We compared vection strengths between the translational motion in the sky or on the ground. Optical flows were captured with a drone (parrot). We recorded eight types of movies of three different translations, which were on the ground condition, the lift-off condition and the diagonal rise condition. The results showed that vection strength was the largest in the ground condition rather than the other two flying conditions. Vection strength can be affected by the ways of the translations.

Multisensory

A Common Mechanism Processes Auditory and Visual Motion

David Alais[1], Uxía Fernández Folgueiras[2] and Johahn Leung[1]
[1]School of Psychology, University of Sydney, Australia
[2]Department of Biological Psychology and Health, Universidad Autónoma de Madrid, Spain

We tested for common processing of auditory and visual motion. Visual or auditory stimuli drifted left or right at various speeds. Observers discriminated speed on each trial, comparing current speed to the average of all speeds (method of single stimuli), and mean perceived speed was calculated. We tested the adaptive relationship between consecutive trials in a sequential dependency analysis. Vision-only: Motion was perceived faster after a slow preceding motion (and vice versa). This is a negative dependency – the classic 'repulsive' motion aftereffect (MAE). Audition-only: The same negative serial dependency occurred, showing repulsive MAEs occur in audition. Visual and auditory alternating each trial: Whether vision preceded audition or audition preceded vision, negative (repulsive) serial dependencies were observed. As the same MAE occurs, despite the adaptor changing modality, we conclude a common, supramodal mechanism processes motion regardless of visual or auditory input.

The Role of Vision in the Integration of Allocentric Information While Moving Through Space

Luigi F. Cuturi[1], Giulia Cappagli[1], Paolo Alborno[2], Gualtiero Volpe[2], Elena Cocchi[3] and Monica Gori[1]
[1]Unit for Visually Impaired People, Istituto Italiano di Tecnologia, Italy
[2]Casa Paganini, DIBRIS, University of Genoa, Italy
[3]Istituto David Chiossone Onlus, Italy

The triangle completion task allows to study the integration of spatial navigation abilities with multisensory cues to build an allocentric representation of space. We investigated the ability of sighted and visually impaired children to spatially update their own position after turning angles to the right or left. The influence of an auditory allocentric reference was tested using a speaker positioned relative to the trajectory origin. Guided by the experimenter, participants walked along the first two legs that compose the triangle, then they were asked to walk along the third leg without support. Younger children performed worse than older peers, thus indicating the role of the developmental stage in understanding the turned angle. Visual impairment influences the capability of updating own positon in space. Our results throw light on the role of vision in gaining the ability to integrate allocentric information while moving, fundamental to accomplish functional spatial navigation.

Visual and Haptic Cue Integration for Multisensory Grasping

Robert Volcic and Ivan Camponogara
Department of Psychology, New York University Abu Dhabi, UAE

The target of a grasping action is usually represented in visual coordinates, but additional haptic cues are available when we grasp with one hand an object held by the other hand (i.e., multisensory grasping). Here, we investigate which visual and haptic cues to objects' distance and size are integrated by measuring grasping performance in unisensory (V and H) and multisensory conditions (VH-full and VH-distance). In VH-full, all visual and haptic cues were available. In VH-distance, only the haptic egocentric distance of the object was provided together with full vision. The availability of both vision and haptics (VH-full) produced faster movements with considerably smaller maximum grip apertures than in the unisensory conditions indicating strong cue integration. Critically, in VH-distance, grasping movements were indistinguishable from those in VH-full. These findings show that haptic cues to distance together with visual cues are sufficient for optimal multisensory grasping.

Judgments of Visual and Somatic Inclination: Evidence Against the Visual Capture

Atsuki Higashiyama and Tadashi Yamazaki
Department of Psychology, Ritsumeikan University, Japan

We investigated an interaction of visual inclination of a scene and the somatic inclination of a floor. One view, which was originally advocated by Berkeley for distance perception, is that the visual image of our surroundings is interpreted by somatic information that is conveyed by muscle spindles, tendons, and cutaneous touch organs of bodily segments. The opposite view, known as visual capture, is that when visual information conflicts with tactile information, the visual information dominates the tactile information. In one condition of our study, visual inclination of a scene was verbally judged by 20 observers while being erect on an inclined floor. In other condition, somatic inclination of the floor was verbally judged by the same observers while looking at an inclined scene. It was found that floor inclination affected the visual judgments, but scene inclination did not affect the somatic judgments. This implies somatic information dominates visual information.

The Risk Assessment of Threatening Stimuli Is More Accurate

Achille Pasqualotto[1,2] and Magda L. Dumitru[3]
[1]Sabanci University, Turkey
[2]Nanyang Technological University, Singapore
[3]Psychology and Neuroscience of Cognition Research Unit, University of Liège, Belgium

A common target of extensive empirical research has been the phenomenon of 'risk compensation', which is the tendency of increasing risk-taking when wearing protective equipment. We tested risk compensation behaviour using a visual perception task where participants wore either a hard helmet or a baseball cap to estimate the distance from themselves to images of threatening and neutral animals. Here, risk compensation translated as distance overestimation, hence as perceiving images as more distant. Is risk compensation affected by the nature of the images? We found that wearing a hard helmet generated over-estimations of distances to neutral images only, thus suggesting that risk assessment of potentially dangerous stimuli was quite accurate and little affected by risk compensation in helmet wearers. We explain these findings from the perspective of the evolutionary importance of risk assessment.

Bimodal Integration: The Interplay Between Perception and Working Memory in *n*-Back Performance

Gregor Hardiess, Niclas Renner and Hanspeter A. Mallot
Department of Biology, University of Tübingen, Germany

Cue integration incorporating multiple sensory modalities is a common process when perceiving natural (multimodal) stimuli. While the perceptual facilitation of multimodal cues is thought to result from combining the unimodal ones, the integrative mechanism of multimodal attention and the built-up of a beneficial working memory (WM) representation remain unclear. Thus, the aim of the study was to investigate and quantify the contributions of (a) perceptual and (b) memory processes in order to understand the supporting effects of bimodal stimulation on *n*-back (executive) WM performance. Hence, we assessed different perceptual thresholds of the relevant uni- and bimodal spatial cues separately for each subject and tested the two-back performance for all cue conditions (visual, auditive, and visual-auditive) according to these thresholds. Comparing perceptual and WM performances and their respective, beneficial interplay, we provide new results about the role of cue integration in spatial cognition.

Attentional Engagement for Synchronous Audiovisual Signals

Hanne Huygelier, Armien Lanssens, Johan Wagemans, Raymond van Ee and Céline R. Gillebert
Department for Brain and Cognition, KU Leuven, Belgium

Previous studies suggest that multisensory stimuli facilitate voluntary attentional control relative to unisensory stimuli. Here, we studied whether attentional processes are modulated by the synchronicity between auditory and visual looming signals using two classic paradigms. In Experiment 1, we adapted the Posner paradigm to test whether the cue validity effect was smaller for synchronous compared to asynchronous audiovisual targets. The results showed a cue validity effect but no interaction between cue validity and audiovisual synchronicity. In Experiment 2, we used the sustained attention to response task to measure the variability in response times in a synchronous and asynchronous audiovisual looming condition. The results showed no effect of audiovisual synchronicity on response time variability. To conclude, our results for the tasks examined do not support the hypothesis that attentional engagement is enhanced for synchronous compared to asynchronous audiovisual signals.

Broad Audio–Visual Integration Is Associated With Poorer Reading Skills in Typical Readers

Marco Turi[1], Paola Fruscoloni[2] and David Burr[2]
[1]Department of Translational Research on New Technologies in Medicine and Surgery, University of Pisa, Italy
[2]Department of Neuroscience, Psychology, Pharmacology and Child Health, University of Florence, Italy

Reading is an audio–visual process that requires learning and automatization of systematic links between graphemes and phonemes. It has recently been suggested that individuals with dyslexia have atypicalities in audio–visual temporal integration. Here, we investigated whether multisensory integration could account for variability in reading skills in a group of young adults with no history of developmental disabilities using three different audio–visual tasks: width of audio–visual temporal binding window, degree of rapid audio–visual recalibration, and susceptibility to the sound-induced flash illusion. After taking into account age and IQ, differences in multisensory integration explain a consistent part of the variance (around 30%) in reading abilities. These results suggest that reading impairments might reflect an audio–visual processing deficit, leading to the idea that development training programs focused on multisensory processing could help to ameliorate reading disorders.

Perceived Simultaneity of Audio–Visual Events Depends on the Relative Stimulus Intensity: A Model

Ryan Horsfall, Sophie Wuerger and Georg Meyer
School of Psychology, University of Liverpool, UK

The points of subjective simultaneity (PSS) obtained from simultaneity judgement (SJ) and temporal order judgement (TOJ) tasks have been shown to be uncorrelated. The multisensory correlation detector (MCD) model accounts for this lack of correlation whilst assuming identical early processing mechanisms but different task-specific weightings. Thirty-four observers (20–69 years of age) performed both SJ and TOJ tasks with identical flash/bleep stimuli (100 milliseconds) with varying stimulus onset asynchronies (−200 milliseconds AV to +200 VA) and two flash intensities (1.1 or 366 cd/m^2). No correlation was found between the PSSs of the tasks but reducing the flash intensity led to a significant PSS shift. We added an early nonlinearity to the MCD model. This delays lower intensity signals to account for the known effect of stimulus intensity on processing latency. When the extended MCD model is fitted to our preliminary data, an intensity-dependent PSS shift is predicted for both tasks.

Action-Induced BOLD Modulation of Sensory Cortices in a Multisensory Distance Reproduction Task

Milosz Krala[1], Bianca van Kemenade[2] and Frank Bremmer[1]
[1]Department of Neurophysics, Center for Mind, Brain and Behavior, University of Marburg, Germany
[2]Department of Psychiatry and Psychotherapy, Center for Mind, Brain and Behavior, University of Marburg, Germany

Self-motion is multisensory and mediated by action. We aimed to identify the neural substrate of audio–visual processing of self-controlled self-motion by means of functional magnetic resonance imaging. The subjects' task was to reproduce (active) a previously perceived linear self-displacement (encoding). Trajectories of active self-motion were recorded and played back to subjects in another set of trials (replay). Comparing active and replay condition, we found action-enhanced blood oxygenation level-dependent (BOLD) responses in respective primary sensory cortices during visual, auditory, and bimodal stimulation. The angular gyrus and the medial frontal cortex showed action-suppressed BOLD responses. In both, enhanced and suppressed areas, behavioral performance correlated with BOLD response. We conclude that (a) continuous monitoring of action consequences increases BOLD responses in primary sensory areas and that (b) the angular gyrus subserves the function as comparator for action-related predictions and sensory outcomes. The study was funded by DFG: CRC-135.

Visual Size Perception and Haptic Calibration After Late Emergence From Blindness

Hafsah Ahmad[1], Monica Gori[1], Alessia Tonelli[1], Muhammad Nabeel Anwar[2] and Giulio Sandini[1]
[1]Unit for Visually Impaired people, Robotica, Brain and Cognitive Sciences, Italian Institute of Technology, Italy
[2]School of Mechanical and Manufacturing Engineering, National University of Sciences and Technology, Pakistan

Visual size constancy starts developing in first years of life. Younger children are proved to show under-estimation of size for distant objects, which reduces with growing age, thus, size constancy matures with years of visual experience. But what happens in the absence (or deprivation) of vision during these crucial years of life? We studied size constancy in visual and haptic domain in seven Pakistani children (aged 9–13 years) with bilateral, early on-set cataract, which was treated surgically during early years of birth. We found that cataract removed children are more precise in judging size in both domains compared to age-matched controls, proposing that even small residual vision is enough to gain visual experience for size constancy,

further, early visual impairment helps in gaining better haptic precision then controls, suggesting that low residual vision in children takes to cross-calibration of vision and touch as already proved for blind children.

The Flexible Use of Internal Predictions and Online Feedback Depends on the Availability of Multisensory Information During Action Planning and Execution

Ivan Camponogara and Robert Volcic
Department of Psychology, New York University Abu Dhabi, UAE

Precision of aiming reaching movements is usually higher when performed toward visuo-haptic targets compared to visual or haptic only targets. Movement execution also depends on the interactions between internal motor predictions and online feedback control. However, the role played by sensory integration in the different phases of motor control is still unclear. Here, we show that when movements are directed toward haptic targets, the concurrent availability of vision during movement planning and shortly after movement onset results in a higher reaching precision compared to when vision is only provided in the final phase of the movement. The visuo-haptic integration in the planning phase can take place in as little as 50 milliseconds and leads to a higher precision than when movements are under haptic guidance only. These findings suggest that motor control strategies can be flexibly selected according to the availability of multisensory information during action planning and execution.

Effect of Color on Audiovisual Integration

Sung-En Chien[1], Yi-Chuan Chen[2], Akiko Matsumoto[3], Wakayo Yamashita[3], Kuang-Tsu Shih[4], Sei-Ichi Tsujimura[3] and Su-Ling Yeh[1]
[1]Department of Psychology, National Taiwan University, Taiwan
[2]Department of Medicine, Mackay Medical College, Taiwan
[3]Faculty of Science and Engineering, Kagoshima University, Japan
[4]Graduate Institute of Communication Engineering, National Taiwan University, Taiwan

We examined the modulation of background color on the speed of visual processing with respect to auditory processing using simultaneity judgment task: A flash and beep were presented at different stimulus onset asynchronies (SOAs), and participants had to judge whether the two stimuli were simultaneous. The participants were more likely to make simultaneous responses when the flash slightly preceded the beep in the red than blue background. This effect can be due to top-down modulation of attention that facilitates parvo but inhibits magno system in red light or bottom-up modulation by the input from intrinsically photosensitive retinal ganglion cells (ipRGCs) that is sensitive to blue light. We then demonstrated that the participants' performance was similar when the levels of ipRGC stimulation were manipulated using color metamers as background. We suggest that the shift of perceiving audiovisual simultaneity in red background is attributed to attentional decrement in visual temporal processing in red light.

fMRI Activities in the Visual Cortex by Olfactory Stimulations

Yoshiaki Tsushima, Yurie Nishino and Hiroshi Ando
Center for Information and Neural Networks, National Institute of Information and Communication Technology, Japan

Last year at European Conference on Visual Perception, we reported that olfactory stimulation affects visual motion perception. This year, we investigated whether or not olfactory stimulation manipulates functional magnetic resonance imaging (fMRI) activities in the visual cortex. With an up-to-date fMRI compatible olfactory stimulation system, we conducted a series of vision-olfactory experiment in fMRI. In a trial, participants viewed motion dots and reported motion dots speed as slower or faster. At the same time, they were exposed to one of the three olfactory stimulations; more specifically lemon, vanilla, or odor-free. The results showed that fMRI activities in the visual cortex were changed with the type of olfactory stimulation. This finding indicates that the neural system in the visual cortex was directly or indirectly influenced by olfactory stimulation. This might give us some clues to explain the reason why olfactory stimulation affects visual motion perception.

Do Odors Influence Color Perception Thresholds?

Mark Greenlee[1], Marija Soldo[1], Laura Albrecht[1], Wilhelm Malloni[1], Mirko Galardi[2], Tina Plank[1] and Maria Michela Del Viva[2]
[1]Department of Experimental Psychology, Universitaet Regensburg, Germany
[2]Dipartimento di Neuroscienze, Università degli Studi di Firenze, Italy

Studies on multisensory perception have shown multiple cases of interactions between olfaction and vision, where an influence of color on odor perception has been demonstrated. In this study, we investigated the effect of

congruent or incongruent odors on color perception thresholds. As of date, 12 participants viewed on each trial gray or colored (red, green, blue, and yellow) rings of four saturation levels on a gray noisy background, while congruent or incongruent odors (strawberry, mint, and lime) were presented via an olfactometer. In a two-alternative forced choice task, they had to decide whether the ring was colored or gray. A repeated measures analysis of variance with the factors odor, color congruency, and saturation level revealed a significant main effect of odor ($p = .003$), a significant main effect of saturation level ($p < .001$), and a significant interaction Odor $\times$ Color Congruency ($p < .001$) on detection performance. The results point to subtle influences of odor on color perception thresholds.

Prior Experience of Stimulus Co-Occurrence Increases Sensitivity to Visual Temporal Asynchrony

Helga Reguly, Márton Nagy, Benjamin Márkus and Jozsef Fiser
Department of Cognitive Science, Central European University, Hungary

The temporal relationship between sensory events plays a crucial role in establishing causal link between them, for example, inferring a common cause. In the current study, we manipulated the probability of co-occurrence of various visual stimuli pairs to see whether this manipulation would affect participants' ability to separate the two elements of a pair in time, when presented asynchronously. We used a simultaneity judgment task, with a learning phase, in which participants saw synchronously disappearing shape pairs, and a test phase, in which three types of pairs (learned, newly combined, and novel) were presented, while the asynchrony between the disappearance of the elements was manipulated. Contrary to earlier results with cross-modal stimuli, a lower proportion of simultaneity judgments, as quantified by shorted temporal binding windows, was reported for the learned pairs than for the newly combined or novel visual pairs indicating an increased probability of unisensory binding.

Shape to Sound Correspondences in Natural Languages

Kuntal Ghosh[1], Keerthi S. Chandran[1] and Swati Banerjee[2]
[1]Center for Soft Computing Research, Indian Statistical Institute, India
[2]Machine Intelligence Unit, Indian Statistical Institute, India

It is known that certain visual stimuli can evoke sensations in auditory pathway as in synesthesia. Synesthetic condition in its mild form may be present in all human beings, which may explain the Kiki–Bouba phenomenon in which human subjects match a jagged figure as Kiki and a rounded figure as Bouba if they are given a choice to do so with the words. The phenomenon could have played a part in the evolution of language. In the present study, we probe the computational mechanisms by which a subject matches a round figure with one word and a sharp figure with another. The subjects were presented with word for an angular object "sword" and nonangular object "cotton" from various unknown languages. The subjects had a tendency to match the word for sword with the angular figure and word for cotton with rounded figure when presented with those word pairs. The words that subjects matched with jagged figure were found to have more high-frequency components with respect to the other words.

Effects of Sensory Modality and Spatial Characteristics of Value-Related Cues on Visual Sensitivity

Roman Vakhrushev and Arezoo Pooresmaeili
Department of Perception and Cognition, European Neuroscience Institute Göttingen, Germany

We compare effects of simultaneous presentation of value-related sounds and colors on visual orientation discrimination. Participants associated two colors and two sounds with either high- or low-reward value. When a Gabor stimulus (diameter 2° presented at 9° eccentricity) is surrounded by a squared frame (size = 10°), frame colors associated with high reward increase visual sensitivity (d'), while high-reward sounds decrease d' compared to low-reward colors and sounds. Next, we decreased Gabor-frame size ratio to $1/2$. Now, value-related sounds increased visual sensitivity, while colors showed an opposite or no effect. Importantly, as the relative Gabor-frame size decreased, the d' difference between ipsilateral and contralateral cues decreased as well, suggesting that target and value-related cues were grouped into a single object. These results indicate that the size of receptive fields that underlie cross-modal value effects differs from those that mediate effects within the same modality.

On the Other Hand: Examining Whether Recognition and Action Affect Multi-Sensory Representation of the Mirrored Bodily Self

Alan O'Dowd and Fiona Newell
School of Psychology, Trinity College Dublin, Ireland

There is evidence that the multisensory representation of bodily self is poor but highly adaptable. To investigate these limits, we employed a visuo-tactile congruency task (CT) during which a mirrored image of the participant's hand, other or fake hand, and control object was presented (Experiment 1). Analysis confirmed a cross-modal congruency effect (CCE) for reaction time and accuracy but no variation across stimuli. Accuracy was lower on self-hand versus other and fake hand trials but comparable to the control stimulus. In Experiment 2, participants moved synchronously or asynchronously with the same stimuli before the CT. A CCE was found, but movement did not influence this cross-modal effect across stimuli, despite existing evidence that action is a salient cue to self. Finally, a third of participants did not recognise their own hand. These findings imply that self-body recognition is insufficient to affect cross-modal interactions, unaffected by action and possibly reliant on other self-cues.

Effect of Uncertainty in Audio–Visual Cross-Modal Statistical Learning

Márton Nagy, Helga Reguly, Benjamin Márkus and Jozsef Fiser
Department of Cognitive Science, Central European University, Hungary

We investigated visuo-auditory statistical learning by using four visual shapes and four auditory sound pairs and creating strong and weak cross-modal quadruples through manipulating how reliably a visual and an auditory pair occurred together across a large number of audio–visual scenes. In Experiment 1, only the weak and strong quads were used, while in Experiment 2, additional individual shapes and sounds were mixed in to the same cross-modal structures. After passive exposure to such scenes, participants were tested in three familiarity tests: (T1) visual or auditory pairs against pairs of randomly combined elements unimodally, (T2) strong cross-modal quads against weak ones, and (T3) visual or auditory pairs from the strong and weak quads against each other, unimodally. Without noise (Experiment 1), participants learned all structures but performed at chance in T3. In Experiment 2, while T1 auditory was at chance, in the auditory T3, participants preferred strong pairs, showing a strong cross-modal boost.

Audiovisual Interactions in Emotion Perception for Communication

Minke de Boer[1], Deniz Baskent[1] and Frans W. Cornelissen[2]
[1]Otorhinolaryngology, University Medical Center Groningen, the Netherlands
[2]Experimental Ophthalmology, University Medical Center Groningen, the Netherlands

Information from multiple modalities contributes to recognising emotions. Most research into emotion perception has relied on static stimuli, whereas natural communication is characterised by its dynamic nature. Hence, it is important to study sensory interactions using dynamic stimuli. We explored such interactions using an emotion-from-speech recognition task in two unimodal (audio and video) and one bimodal condition in healthy observers. Preliminary results suggest that multimodal information is integrated during emotion recognition but not treated equally; visual information is more important than auditory information. In addition, gaze data show that people focus more on the eyes when audio is present, whereas they look more towards the mouth when audio is absent, suggesting they lip read in order to extract more information. It therefore appears that observers do not always prioritise the eyes for emotion recognition but use gaze functionally as an information-gathering method.

Causal Relationship Attracts Timings of Two Events Given to Different Modalities

Hiroyuki Umemura
Human Informatics Research Institute, National Institute of Advanced Industrial Science and Technology, Japan

The present study investigated how causality modifies perceived timing of two events given to different modalities. For the purpose, I prepared a set of stimuli which simulated a causal situation; a falling ball hit a floor and vibration occurred. In the experiment, subjects were required to judge whether the timings of ball contacting and vibration were simultaneous or not. The vibration was given with a haptic device around the timing of ball contacting with various temporal intervals. The position of the vibration was coincided with the visual position of the ball contacting. Three directions were prepared for the vibration to examine effects of validity of causality between two events. The results showed that when the direction of the vibration was accorded with the direction of ball falling, two events were more frequently perceived as simultaneous. This indicates that two events given to different modalities attracted each other when causality was appropriately established.

Haptic Perception of Softness Is Influenced by Memory

Anna Metzger and Knut Drewing
Department of General Psychology, Justus-Liebig University Giessen, Germany

Visual perception of an object's property (e.g., its typical colour) can be affected by the memory of it. We showed that the memory of the softness of familiar objects influences their haptic perception. We used silicone rubber stimuli, one half of which was covered with a layer of a familiar object (sponge, wood, tennis ball and foam ball). Participants did not see the stimuli and were told that they explore familiar objects. They first stroke laterally with their bare finger over the covering layer to recognise the familiar object and then indented the uncovered part of the stimulus with a probe. The task was to compare the softness of bipartite stimuli to that of neutral silicone stimuli. In a control condition, two neutral silicone stimuli were compared. Softness judgements were shifted towards the known softness of the familiar object, indicating that haptic softness perception is affected by memory.

The Effect of Pre-Period Design in Multisensory RT Experiments

Cleopatra Pike and Thomas Otto
School of Psychology and Neuroscience, University of St Andrews, UK

Reaction times (RTs) are faster with multisensory than unisensory signal. This 'redundant signal effect' (RSE) occurs with various experimental designs. However, variation in experimental design can create variation in RSE, making it difficult to compare RSE across studies. For example, the pre-period distribution (stimulus waiting time) varies widely across studies and is known to alter unisensory RTs. Therefore, it could also alter multisensory RTs and RSE. We tested the effect of pre-period distribution on RSE using audio–visual stimuli and a 2×2 design (we tested uniform vs. exponential and long- vs. short pre-period distributions). Firstly, we replicated the effect of pre-period on unisensory RTs. We also showed effects with multisensory signals. Then, in a systematic analysis of the RSE using a model-based approach, we showed that pre-period does not ultimately affect the RSE. We conclude that the mechanisms behind RSE are robust, making a comparative approach across studies feasible.

The Visually Evoked Auditory Response and Sensory Excitability: A New Internet Survey

Elliot Freeman
Department of Psychology, City University of London, UK

Some people hear what they see. We previously found that ratings of the auditory vividness of silent videos correlated with a variety of personal traits. However, the videos depicted real-world events, thus semantic associations with sounds might have biased ratings, while 'yea-saying' could account for correlated video and trait ratings. Here, we used abstract meaningless videos, and randomly assigned normal or reverse-coded versions of each trait question to each respondent. Over 1,500 respondents completed our Internet survey. Despite reverse-coding, video ratings were strongly positively correlated with ratings of musicality, susceptibility to earworms, tinnitus, auditory-evoked phosphenes, migraine, pattern glare, photic sneezing, insomnia and poor speech-in-noise comprehension. The association of visually evoked sounds with such diverse unimodal and cross-modal phenomena supports systemic disinhibition or excitability of auditory and visual cortices and their interconnections.

Effects of the Direction of Hand Motion and the Perspective Cue on Proprioceptive Drift

Hiroaki Shigemasu[1] and Uki Uchida[2]
[1]School of Information, Kochi University of Technology, Japan
[2]Graduate School of Engineering, Kochi University of Technology, Japan

Previous studies have demonstrated that the perceived position of the hand was shifted by the active and synchronous movement of visually displaced virtual hand. In this study, we examined whether the proprioceptive drift depends on (a) the direction of hand motion (left and right or back and forth directions), (b) the congruency of the motion and displaced direction of the hand, and (c) the perspective cue in the back and forth movement using a head-mounted display showing binocular disparity cue. The results showed that the amount of the drift was significantly smaller in the back-and-forth direction than the horizontal hand motion, while the congruent direction of motion and displacement did not show larger drift. In the back-and-forth motion, the drift did not depend on whether the retinal size of the virtual hand changed according to depth position. These results suggest that the retinal motion caused larger effects on the drift than the change of disparity and retinal size.

Recalibration of Audio–Visual Simultaneity Judgment Depends Upon Awareness of Temporal Lag

Masaki Tsujita[1] and Makoto Ichikawa[2]
[1]Research Center for Advanced Science and Technology, The University of Tokyo, Japan
[2]Faculty of Letters, Chiba University, Japan

Simultaneity judgment between auditory and visual events is adaptively recalibrated after repeated exposure to an audio–visual temporal lag. Our previous study reported that the recalibration of motor–visual simultaneity judgment is independent of awareness of adapted temporal lag. In order to understand the differences of processing underlying the recalibration between audio–visual and motor–visual domain, we examined dependency of the recalibration of audio–visual simultaneity judgment upon awareness of the temporal lag. Observers were allocated either of the two conditions; in the unaware of lag condition, a slight lag was introduced at first and gradually increased during adaptation, while in the aware of lag condition, a substantial lag was introduced throughout adaptation. We found significant recalibration only in the aware of lag condition. These results suggest that nonautomatic, top-down processing is involved in the recalibration of the audio–visual simultaneity judgment.

Integration of Visual, Proprioceptive and Vestibular Information During Distance Perception in the Personal Space

Tijana Todić Jakšić[1] and Oliver Tošković[2]
[1]Department of Psychology, Faculty of Philosophy, University of Priština, Kosovo
[2]Laboratory for Experimental Psychology, Faculty of Philosophy, University of Belgrade, Serbia

The study examines whether distance estimation accuracy depends on the task (verbal or proprioceptive) and participant's disorientation (vestibular information). Twenty-two students judged stimuli egocentric distances (20, 40 and 60 cm) on white platform, at eye level on three ways: judging the standard distance verbally (the verbal estimation task), guiding the experimenter to move the stimuli until it reaches the standard distance (the guidance task) or moving the stimuli by their hand (the motor reproduction task). In half of the trials, participants were disoriented by rotating on a chair. Results show that participants were most accurate in the motor reproduction task, while they overestimated stimuli distance in the guidance task and underestimated it in the verbal estimation task. Since disorientation did not change distance estimates, vestibular information did not affect perceived distance, while proprioceptive information (the motor reproduction task) increased distance estimation accuracy.

Comparison of Olfactory Threshold and Sensory Evaluation Among Three Color Conditions

Akihisa Takemura
Faculty of Science and Engineering, Setsunan University, Japan

There are few studies about multimodal interactions between color and odor. We compared olfactory thresholds and sensory evaluations of odor measured in three colored boxes. Twenty participants in their 20s entered three colored boxes (size 650 × 850 × 1,450H), whose inner walls were covered either by white (N9.5), blue (5PB 4/8), or red (2.5R 4/12) drawing paper. We measured participants' thresholds for acetone and alpha-pinene from odor bags made of polyethylene terephthalate by means of the triangular odor bag method. Moreover, participants were asked to sniff three acetone bags (126, 420, and 1,260 ppm) and three alpha-pinene bags (0.1, 1.0, and 10 ppm) and to refer intensity, hedonics, and impressions. There was no significant difference among thresholds in the three color conditions. Intensity and hedonics evaluations of odor were not affected by color, except for the impression of "warmth." However, the "warmth" of an odor might include not only the impression of the odor but also that of the color.

So Small No Matter How Far – Anisotropy of Perceived Size

Oliver Tošković
Laboratory for Experimental Psychology, Faculty of Philosophy, University of Belgrade, Serbia

Vertical distances are perceived as longer than horizontal ones. According to size–distance invariance hypothesis, this must imply perceived size anisotropy, too. In four experiments, 59 participants matched sizes of dim light stimuli, in a dark room, on horizontal and vertical direction. In first three experiments, they were sitting upright and moving the head, the body or lying on the left side of the body and moving the head. In last experiment, they were sitting upright and moving the head, in virtual reality display. Results show that perceived size does not change with viewing direction in first three experiments, in physical reality. But in virtual reality (VR), size on vertical direction was perceived as smaller than on horizontal. Size distance invariance hypothesis (SDIH) predicts that larger perceived distance would lead to larger perceived size. Our results contradict to those predictions, since in physical reality, there was no change in perceived size, while in VR, larger perceived distance lead to smaller perceived size. This study was supported by Ministry of Education and Science of Serbia, project ON179033.

Object Perception

Evidence for Amodal Completion of Low-Level Detail in Visual Cortex

Jordy Thielen, Sander Bosch, Tessa M. van Leeuwen, Marcel van Gerven and Rob van Lier
Donders Centre for Cognition, Donders Institute, the Netherlands

Amodal completion is the phenomenon where an awareness is created of the presence of the invisible parts of a partly occluded object, even though we do not actually see them. To date, there is no consensus regarding amodal completion of low-level object features, such as contour and texture in visual areas. We measured brain activity while participants perceived partly occluded objects, their mosaic parts, and their complete interpretation. We presented squares and crosses with orientated square-wave gratings as texture. We used multivariate pattern analysis to decode these orientations from functional magnetic resonance imaging voxels, which represented the occluded area and thus were not visually stimulated with grating information. Preliminary results show that we can decode orientations at the area of occlusion from visual cortex. Also, we found a mediating role of global symmetry. This provides evidence for an amodal representation of low-level features of the invisible parts of partly occluded objects.

Mechanisms of Medieval Visual Vocabulary in Polychrome Sculpture

Joshua Harvey and Hannah Smithson
Department of Experimental Psychology, University of Oxford, UK

The medieval observer experienced a rich visual environment of religious iconography, typified by polychrome sculpture: metallic base layers with colourful transparent coatings. Reconstructions of these objects elicit experiences of perceived glow, suggesting they reinforced the medieval teaching identifying holiness with luminosity. Through collaboration between art conservators and perceptual scientists, we have characterised the physical and perceptual features of such materials. We adopted a dual approach of using physical samples prepared using documented medieval techniques and physics-based computer-graphics rendering. Spectroradiometric data confirm that the rendering captures properties of the real samples. Whilst overall chromaticity is close to gold, the material also gives rise to perceived gloss, glow, binocular glitter and other features. Medieval polychrome sculpture provides a useful investigative framework for the parameter space of metallic material appearance.

No Holistic Processing of Objects in Brain Regions That Process Faces Holistically, Despite an Identical Behavioural Effect

Celia Foster[1], Mintao Zhao[2], Andreas Bartels[3] and Isabelle Bülthoff[1]
[1]Department of Human Perception, Cognition and Action, Max Planck Institute for Biological Cybernetics, Germany
[2]School of Psychology, University of East Anglia, UK
[3]Vision and Cognition Lab, Centre for Integrative Neuroscience, Germany

Studies have demonstrated that faces are processed holistically, and linked this processing to brain activity in occipitotemporal cortex. Recent work has shown that non-expertise objects can be processed holistically. It remains unclear which brain areas are involved. Our participants performed a composite task with objects, while we recorded their brain activity with functional magnetic resonance imaging. In addition, we defined brain regions of interest based on their responses to faces, objects, scenes and perceptual grouping. Despite our participants' behavioural holistic processing effect being as strong as for faces, we found that neither regions shown to process faces holistically (in previous studies and our own work) nor any other brain regions we investigated, showed activity consistent with holistic processing. We conclude that different brain regions may underlie holistic processing of faces and objects, but further work is needed to elucidate which brain regions underlie holistic processing of objects.

Semantic Processing in Scenes and Sentences: Investigating Shared Neural Patterns Using MVPA

Dejan Draschkow[1], Edvard Heikel[2], Melissa L.-H. Vo[1], Christian Fiebach[2] and Jona Sassenhagen[2]
[1]Department of Psychology, Scene Grammar Lab, Goethe University Frankfurt, Germany
[2]Department of Psychology, Interdisciplinary Center for Neuroscience, Goethe University Frankfurt, Germany

A late event-related negativity (N400) is linked to the semantic processing of language. Visual (i.e., non-verbal) stimuli have also shown to elicit an N400-like potential, for example, when objects are shown in incongruent contexts (e.g., a toothbrush in the fridge). It is not known if these two components signify common multi-modal semantic processing or if their similarity is just superficial.

We use multivariate pattern analysis to identify shared neural patterns underlying semantic violations in scenes and sentences. Forty participants were presented with auditory-linguistic as well as visual-scene semantic inconsistencies within the same experiment. We find above-chance classification of congruent versus incongruent word–sentence relationships when the classifier is trained on scenes and vice versa. Our results show that neural patterns shared between the semantic processing of auditory-linguistic and visual-scene information, implying the use of a domain-general multi-modal semantic system.

Nature-Themed Puzzles and the Aesthetic Aha

Susanne Röder[1], Wolfgang Trapp[2] and Claus-Christian Carbon[1]
[1]Department of General Psychology and Methodology, Otto-Friedrich-University Bamberg, Germany
[2]Klinikum am Michelsberg, Sozialstiftung Bamberg, Germany

The present study tested the power of Aesthetic Aha—pleasure generated by Gestalt detection—with people suffering from Alzheimer, the most common type of dementia. Alzheimer patients were asked to puzzle sets of PICSSi jigsaw puzzles displaying different natural environments. We recorded the time participants needed to unravel each puzzle and asked them additionally to perceive the puzzled images on beauty and if they would like to puzzle that image again. We predict that participants will be faster in puzzling images they like compared to those images they perceived less beautiful, and that the interest in puzzling an image again will correlate with perceived beauty of the image. Results are evaluated in the context of aesthetic theories, particularly regarding Gestalt and Aesthetic Aha; the impact of such procedures utilizing PICSSi material will be discussed regarding more general implementations of Gestalt principles in clinics, pension homes, and Ambient Assisted Living.

Violation of Shape Constancy in Mona Lisa Effect

Takao Sato
College of Comprehensive Psychology, Ritsumeikan University, Japan

A person in a portrait is perceived to be facing even when observers move around (Mona Lisa effect), but the width of the face appears narrower. This study aims to evaluate this violation of shape constancy. From a portrait depicting a person facing straight and three-fourth view position, pictures with 0°, 15°, and 30° rotations were generated and presented on a front-parallel cathode-ray tube screen. These pictures were presented with an oval shape comparison stimulus with varying width. Subjective width for each face was measured by comparing the two stimuli. It was found, regardless of the stimulus type, that the subjective width decreased as rotation becomes larger and corresponds to the physical width on the screen. Thus, our results indicate that shape constancy does not occur when pictures were rotated. That is, the three-dimensional representation of object in the visual system keeps the orientation in the original picture independently from the rotations of pictures, and the width is perceived accordingly.

The Influence of Perceived Size on Object Correspondence in the Ternus Display

Madeleine Stepper and Elisabeth Hein
Department of Psychology, University of Tuebingen, Germany

The visual system needs to establish associations between images across space and time in order to maintain object identity, solving the correspondence problem. It has been shown that size can influence correspondence. Here, we investigated whether retinal or perceived size matter using the Delbeouf illusion to manipulate the perceived size of the elements in a Ternus display. This ambiguous apparent motion display consists of three elements, shifted by one position from one frame to the next. Depending on how correspondence is established two different motion percepts can be perceived. If correspondence is influenced by the perceived size of the elements, this should affect the motion percept. We found, however, no influence on the perceived Ternus motion, suggesting either that the illusion was not large enough to be effective or that only retinal and not perceived size can affect correspondence, maybe because correspondence happens at an earlier level of processing than size constancy.

The Representation of Object Hardness in the Brain

Li Guo, Susan Courtney and Jason Fischer
Department of Psychological and Brain Sciences, The Johns Hopkins University, MD, USA

To form predictions about how physical events will unfold, we must estimate the material properties of objects and surfaces in a scene. What brain regions are recruited to infer material properties? We sought to measure the neural encoding of object hardness—a key variable for mental simulation of physical behavior—and test the relative contributions of dorsal and ventral brain areas. In a

functional magnetic resonance imaging experiment, participants judged the hardness of a series of everyday objects. We separately localized dorsal brain regions engaged in the prediction of physical events as well as ventral object-selective areas. A multivariate pattern analysis revealed fine-scaled encoding of object hardness within the dorsal brain regions: Activity patterns varied smoothly with changes in hardness. We did not observe this fine-scaled hardness encoding in ventral regions, suggesting that dorsal stream areas play a key role in representing material information that is relevant for predicting physical dynamics.

The Size Distance Invariance Hypothesis and Binocular Size Perception

Juhun Kim, Joowon Park, Sumin Heo and Nam-Gyoon Kim
Department of Psychology, Keimyung University, South Korea

The present study explored whether the binocular visual system utilizes the size distance invariance hypothesis (SDIH) or an alternative source of information, such as interpupillary distance (IPD) proposed by Kim, to perceive an object's size. In three experiments, participants viewed a virtual object stereoscopically, then judged its size and distance. In Experiments 1 and 2, participants' size judgments were more accurate and less biased than their distance judgments. Partial correlation analyses further demonstrated that perceived (stereoscopic) size and distance are independent, rather than interdependent as the SDIH assumes. Experiment 3 manipulated participants' IPDs, one component of Kim's proposed variable. Size and distance judgments were overestimated under a diminished IPD but underestimated under an enlarged IPD, consistent with predictions based on participants' utilization of the proposed information source. Results corroborate the utility of Kim's proposed variable as a viable alternative source of size information for the binocular visual system.

The Effect of Stimulation Time on Contour Integration

Ling Wang, Yichang Du and Feiyun Huang
School of Life Science and Technology, University of Electronic Science and Technology of China, China

Amount of papers had deeply researched contour integration, but little researches paid attention to the effect of stimulation time on the contour integration. Some regular small Gabors, showed as local feature, can be perceived as a whole contour. By changing the numbers (N) of small Gabors and stimulation time, this project studied the effect of stimulation time on contour integration, especially on curve integration. Our results showed that when the information from local feature were limited, that is, $N < 6$, the contour integration were more likely in the way of bottom-up visual information process, and longer time had little influence; when the information from local feature were enough, that is, $N > 6$, longer stimulation time brought significant better performance, particularly in curve integration, similar with contour integration by global feature. We speculated that top-down memory, experience, and conscious attention might play an important role in this contour integration process due to longer time to remind and synthesize.

Object Recognition

Investigating Viewpoint Dependence in Object Recognition Using Depth Rotated 3D Models in a Sequential Matching Task

Aylin Kallmayer, Dejan Draschkow and Melissa L.-H. Vo
Department of Psychology, Scene Grammar Lab, Goethe University Frankfurt, Germany

Recognizing objects from different viewpoints is a necessary skill for everyday interactions with our environment. The degree of viewpoint invariance in object recognition most likely depends on the context and given task. While recognizing objects at basic level (e.g., deciding a shape is a dog) has previously been described as being viewpoint invariant, the stimuli used were often either rotated on a two-dimensional plane or around the yaw axis in 3D. In the present study, participants were presented with a basic level category label (e.g., "car") followed by a 3D model of an object rotated around the pitch axis (0°, 60°, 120°, 180°, 240°, and 300°) to generate more variant viewpoints. The participants had to decide as quickly as possible whether the object matched the category or not. In contrast to previous findings, our results imply that object recognition at basic level is indeed viewpoint dependent—at least when rotated around the pitch axis—and therefore uses view-specific representations.

The Impact of Semantical Relations on Template Activation

Saliha Reinecke[1], Dejan Draschkow[1], Sage Boettcher[2] and Melissa L.-H. Vo[1]
[1]Department of Psychology, Scene Grammar Lab, Goethe University Frankfurt, Germany

[2]Department of Experimental Psychology, Brain and Cognition Lab, University of Oxford, UK

Target templates play a critical role in cognitive processes such as visual search; however, it is unclear whether information concerning related objects is also contained in such templates. In an electroencephalogram experiment, observers counted the appearance of a target (e.g., a spatula) in a stream of distractors. Distractors were divided among anchor objects, categorically related local objects, and unrelated objects. Anchor objects hold unique spatial information about the target (e.g., stove), categorically related local objects are objects which are semantically related (e.g., pan). The P300 is a component known to be elicited by task-relevant stimulus changes. As expected, we found a P300 response to target items; however, we additionally observed a significant positivity to categorically similar objects. This implies that search templates not only contain information about a specific target but also categorically related objects.

Categorization Task With Blurred Pictures: An ERP Study

Quentin Lenoble, Sebastien Szaffarczyk and Yannick Wamain
SCALab, Université de Lille, France

This study explore whether a low-pass filter (3 c/deg) can modulate the brain electrical activity during a rapid categorization task. Fifteen young participants (mean age: 20.3 years) performed two categorization tasks (animal and furniture target) of flashed (28 milliseconds) gray level pictures presented under normal and filtered condition. Behavioral performances were better for animal in comparison to furniture (−55 milliseconds; + 2% of correct response). The low-pass filter condition induced a decrease in performance for the furniture only (+20 milliseconds; −3% of correct response compare to none filtered). These behavioral findings were associated with neurophysiological correlates revealing higher amplitude of several early components evoked by low-pass filtered animals compared to furniture. We suggest that the increased P100 amplitude for the low-pass filtered animals could support the high level of performance for this specific living semantic category.

Does Font Influence Letter Recognition?

Aleksandra Dobrego, Svetlana Alexeeva and Alena Konina
Faculty of Liberal Arts and Sciences, Laboratory for Cognitive Studies, Saint-Petersburg State University, Russia

Despite of letters being in the spotlight of research on visual information processing, the mechanism of letter recognition remains unclear. We conducted two boundary experiments to check whether the font (fixed-width Courier New vs. proportional Georgia) influences legibility of Cyrillic letters. Participants had to name a letter presented in parafovea (crowded «*?*» or isolated «?») after focusing on a centered fixation cross; the letter disappeared before participant's fixation reached it. As a result, confusion matrices of Cyrillic letters were generated. We found that letter identification efficiency depends on font: Subjects were more efficient naming Georgia letters (72%) than Courier New (46%). Besides, crowded letters in Courier New were harder to identify than the ones in Georgia, while recognition efficiency of isolated letters was almost the same. Since crowded letters imitate real reading, we claim that Georgia is more readable font than Courier New. The study was funded by RSF#14-18-02135.

Decoding the Order of Visual Operations

Jessica Loke, Noor Seijdel and H. Steven Scholte
Brain and Cognition, University of Amsterdam, the Netherlands

Humans recognize objects with remarkable speed. This speed is attributed to feed-forward processing. However, in a cluttered environment, objects that we want to identify are not prominent. Successful recognition involves the visual system's facilitation to identify and single-out partial object representations. This facilitation is attributed to recurrent processing. In this experiment, we investigate the order of these processes using natural images with a visual mask. We collected electroencephalography measurements from 79 participants while they completed an object categorization task. Then, we performed a decoding analysis on the large data set. Our results revealed that there is activity in early visual areas related to segmentation as early as 100 milliseconds. This onset was followed 20 milliseconds later by activity corresponding to occlusion. Both effects could be traced from early- to higher visual areas. This finding expands on our current understanding of object recognition under naturalistic conditions.

Task Predictability Determines Knowledge Acquisition During Object Recognition

Cecile Gal[1], Vasile V. Moca[2], Ioana Tincas[2], Teodora Gliga[1], Marie L. Smith[1] and Raul Muresan[2]

[1]Centre for Brain and Cognitive Development, Birkbeck College, University of London, UK
[2]Experimental and Theoretical Neuroscience Lab, Transylvanian Institute of Neuroscience, România

Images of objects at varying recognisability levels were generated using the "Dots" method. Stimulus presentation order was used to control subjects' access to information: Six participants were presented stimuli in which visibility decreased from one block to the next; six participants were presented with an ascending order; and for six participants, the recognisability level of the stimuli was randomised. Participants experiencing descending visibility accumulated strong knowledge about the objects and exhibited the highest accuracy and lowest uncertainty, especially at intermediate visibility levels. Random presentation resulted in the lowest accuracy, despite having access to more information than ascending. They were also more uncertain than descending ones. This suggests that unpredictability in information presentation can impair knowledge accumulation. Concurrent eye-tracking measures will reveal how this experimental manipulation impacts on participants' exploration of objects.

Further Evidence for Rapid Feedback in Contour Perception

Jan Drewes[1] and Weina Zhu[2]
[1]Physics of Cognition, Technical University of Chemnitz, Germany
[2]School of Information Science, Yunnan University, China

The human visual system is able to extract information from visual input very quickly. Previously, we found evidence of recurrent processing in behavioral performance using a rapid stimulus repetition paradigm, with performance peaking at about 60 milliseconds between two stimulus presentations. Here, we extend the scope of our investigation toward longer durations and higher temporal resolution. We successfully reproduced our previous finding of a fast performance peak at 60 milliseconds ISI, but we found an additional performance peak overlayed to the shorter effect, peaking at about 80 to 90 milliseconds but lasting up to about 300 milliseconds. Noise tolerance increase for a double stimulus presentation compared to a single stimulus ranges from 35% at 25 milliseconds ISI to just more than 80% at 125 milliseconds, then slowly declining to converge against 35% to 40% at 400 milliseconds. This is further behavioral proof for rapid information feedback in visual processing; however, the information appears to be buffered for longer periods than previously reported.

Why Can We Detect the Tilt More Easily for Symmetric Objects Than Asymmetric Ones?

Takashi Ueda[1], Takashi Yasuda[2] and Kempei Shiina[1]
[1]Faculty of Education and Integrated Arts and Sciences, Waseda University, Japan
[2]Faculty of Human Sciences, Matsuyama Shinonome College, Japan

For an object having a symmetric shape, it is possible to judge the objects' tilt sharply. The reason for this superiority of symmetry is that we can more easily detect the "centerline," the axis bisecting an object, for objects that are symmetric rather than asymmetric. In this research, we conducted a tilt judgment experiment using geometrically simple or complicated figures. The results showed that superiority of symmetry in tilt detection even when the figures had unfamiliar shapes. In addition, as a framework to explain the results of this experiment, we proposed a centerline detection process prescribed by the relationship between the observer and the target and discussed its validity.

Perception and Action

A Kind of Magic: The Impact of Motor Expertise on Pantomimed Grasps' Discrimination

Davide Quarona[1], Atesh Koul[1], Caterina Ansuini[1], Luca Pascolini[2], Andrea Cavallo[3] and Cristina Becchio[1]
[1]Cognition, Motion and Neuroscience Unit, Fondazione Istituto Italiano di Tecnologia, Italy
[2]School of Psychology, University of East Anglia, UK
[3]Department of Psychology, University of Torino, Italy

Professional magicians regularly use pantomimed grasps (i. e., movements towards imagined objects) to deceive audiences. To do so, they learn to shape their hands similarly for real and pantomimed grasps. Here, we tested whether this form of motor expertise provides a significant benefit to the processing of pantomimed grasp. To this aim, in a one-interval discrimination design, we asked 17 professional magicians and 17 naïve controls to watch video clips of reach-to-grasp movements and judge whether the observed movement was real or pantomimed. All video clips were edited to produce a spatial occlusion of the to-be-grasped object (either present or imagined). Whereas magicians and controls performed similarly with real grasps, magicians were faster and more accurate than controls at discriminating pantomimed grasps. These findings suggest that motor expertise may be crucial to detect relevant kinematic cues during the discrimination of pantomimed grasps.

Visuomotor Adaptation Is Influenced by Perceived Depth

Carlo Campagnoli and Jordan A. Taylor
Department of Psychology, Princeton University, NJ, USA

When repeatedly pointing to a target, movement direction is continually updated as a function of the error between where one plans to reach and the visual feedback. Spatial vision is therefore critical for motor adaptation; however, previous results have shown that depth perception is highly inaccurate. Here, we investigated how potentially faulty depth signals influence visuomotor adaptation. In a study using virtual reality (VR), participants were instructed to throw a cursor at the center of a target. The cursor always hit off by a fixed horizontal offset regardless of reaching direction, causing a gradual adaptation unbeknownst to the subjects. Crucially, this motor learning was stronger when no three-dimensional (3D) cues were available compared to when the visual scene was richer. These results mirrored those of a perceptual task where the target appeared to occupy a greater retinal area when no depth information was available. We conclude that visuomotor adaptation is influenced by 3D cues similar to perception.

Effects of Shooting Performance on the Estimated Size of a Basketball Hoop

Carl Granrud, Tristan Lyle, Pearl Marquez, Alana Reed and Emma Rogers
Department of Psychological Sciences, University of Northern Colorado, CO, USA

Past studies reported that observers' actions toward objects influence their judgments of objects' sizes. For example, Witt found that participants judged a golf cup as larger if they were successful at making putts and smaller if they were less successful. However, other studies suggest that these effects apply only to size estimates made from memory. The present study asked whether shooting performance influences the estimated size of a basketball hoop. Participants attempted basketball shots while standing on one or two feet, then estimated the diameter of the hoop while the hoop was in view or out of sight. Participants who stood on two feet made more baskets and made larger, more accurate size estimates than those who stood on one foot, and shooting success correlated significantly with estimated size, when size was estimated with the hoop in view and when it was estimated from memory. The results suggest that actions toward objects can influence the judgments of objects' sizes.

Asymmetric Effect of Distractor Graspable Objects on Successive Actual Grasps

Veronica Pisu, Stefano Uccelli, Lucia Riggio and Nicola Bruno
Dipartimento di Medicina e Chirurgia, Università di Parma, Italy

Suppose you see a first object and then have to grasp a second object. Will the first object affect the preparatory processes for grasping the second? In an open-loop paradigm, we measured preview times and grasp kinematics for stimuli preceded by the presentation of distractors that elicited either a congruent or incongruent motor representation. We compared three types of precision grasps (pincer, tripod, and pentapod). Results suggest that preview times for incongruent objects are increased relative to baseline, but only when the implicitly elicited preparatory process is less precise than the sensorimotor process of the actual grasp (e.g., when the initial object elicits a pentapod grasp, whereas the grasped object requires a pincher grasp). When the initial implicit grasp is more precise than the actual grasp, the effect is negligible. These results document a novel effect of context on grasping and highlight the role of precision on sensorimotor preparation.

Enhancement of Vection by Optical Flow With Multiple Colors

Yasuhiro Seya[1], Keiko Shiozaki[2] and Hiroyuki Shinoda[2]
[1]Department of Human Informatics, Aichi Shukutoku University, Japan
[2]Department of Information Science and Engineering, Ritsumeikan University, Japan

It is well known that stimulus color can affect vection. However, previous studies have reported mixed results; some studies have shown that stimulus color might enhance vection while other studies have reported the inverse. To clarify the effects of stimulus color on vection, we conducted two experiments. In both experiments, participants viewed an expanding optical flow composed of two or four equiluminant colors (Experiment 1) or four, six, or seven equiluminant colors (Experiment 2). Participants reported vection by pressing and holding a button whenever they felt vection. After each trial, they also rated the magnitude of vection. The results showed that, overall, optical flow with multiple colors induced stronger vection, as compared with that induced by optical flow composed of white dots. The enhancement of vection did not change with increasing number of colors included in the optical flow.

A Dorsal Illusion Affects Perception and Action in the Same Way

Cristina de la Malla[1], Eli Brenner[1], Edward de Haan[2] and Jeroen B. J. Smeets[1]
[1]Department of Human Movement Sciences, Vrije Universiteit Amsterdam, the Netherlands
[2]Department of Psychology, Amsterdam Brain and Cognition, University of Amsterdam, the Netherlands

The two visual systems hypothesis (TVSH) states that vision for action is processed veridically in the dorsal pathway, independent from that for illusion-prone perception in the ventral pathway. We evaluated speed perception and its use for interception in a subject with a bilateral ventral lesion and in 10 control subjects. The TVSH would predict that a perceptual illusion would not affect interception in any of our subjects, but a ventral lesion would make it impossible to judge the target's speed. If information is not processed differently for perception and action, and all motion is processed in the dorsal pathway, the subject with a lesion would be influenced by the illusion as controls are. Our experiment showed that all subjects' errors in interception matched the errors expected given their perceptual errors. This provides clear evidence against the TVSH. The ventral pathway appears not to be involved in any task requiring motion processing.

Investigating the Interaction Between Emotion Perception and Postural Control: Effects of Stimuli Properties and Individual Characteristics

Angélique Lebert[1], Laurence Chaby[2], Chloé Garnot[3] and Dorine Vergilino-Perez[1]
[1]Institut de Psychologie, Laboratoire Vision Action Cognition, Université Paris Descartes, France
[2]Institut de Psychologie, Sorbonne Université & CNRS, France
[3]Institut de Psychologie, Université Paris Descartes, Sorbonne-Paris-Cité, France

A crucial aspect of understanding human behavior relates to the interaction between perception and action. Thus, during social interactions, perception of emotions in our environment can trigger behavioral responses like approach and avoidance reactions. Here, we assess how the perception of emotions affect postural control and action tendencies by contrasting different types of stimuli. Participants were passively exposed to static (faces) or dynamic stimuli (movies) expressing different types of basics emotions (joy, fear, anger, sadness, disgust, and neutral). The analyses of sway length and mean velocity of the center of pressure showed a greater impact of dynamic than static stimuli on postural stability. Moreover, the results on the center of pressure on the anteroposterior axis were discussed in light of the approach-avoidance model by considering how some traits of personalities (e.g., aggressiveness, empathy, anxiety) modulate the relation between emotion and posture.

An Active/Multi-Passive Viewing Advantage in Immersive Virtual Environments

Marta Stragà[1], Sara Rigutti[1], Marco Jez[2], Giulio Baldassi[1], Andrea Carnaghi[1], Piero Miceu[2] and Carlo Fantoni[1]
[1]Department of Life Sciences, University of Trieste, Italy
[2]Area Science Park, Arsenal s.r.l., Italy

We studied the link between the type of vision experienced in a collaborative immersive virtual environment (active/passive), the type of error one looks for during a cooperative multi-user exploration of a design project (affordance/perceptual violations) and the type of setting in which users perform (natural/controlled). We used an ecologically valid yoking paradigm and found that the likelihood of error detection was governed by an active versus multi-passive viewing advantage dependent on the degree of (a) knowledge dependence of the type of error the observers look for, with the active versus passive advantage occurring irrespective from the setting for affordance (high dependence) but not for perceptual (low) violations and (b) social desirability induced by the setting, being the active versus passive advantage for perceptual violations absent in a natural (Experiment 1) not in a controlled (Experiment 2) setting. Results are challenging for the traditional view on three-dimensional active/passive vision.

Neural Correlates of Visual Grasp Selection

Lina K. Klein[1], Guido Maiello[1], Daria Proklova[2], Juan Chen[2], Vivian C. Paulun[1], Jody C. Culham[2] and Roland Fleming[1]
[1]Department of Psychology, Justus-Liebig University Giessen, Germany
[2]Department of Psychology, Brain and Mind Institute, University of Western Ontario, Canada

We investigate how humans visually select grasps onto three-dimensional objects. In behavioral experiments, human participants ($n = 26$) picked up objects of wood and brass. Grasp patterns were significantly modulated by object shape, yet the same shapes were grasped at different locations depending on their orientation relative to the observer in order to satisfy the postural constraints of the arm and hand. Mass and mass distribution also systematically affected grasp locations. We employed these findings to design a functional magnetic resonance imaging

experiment in which participants ($n = 8$) grasped new objects at pre-selected grasp positions. We designed grasps to be optimal in terms of grasp-relevant object information such as mass but suboptimal with respect to hand posture, and vice versa. By contrasting brain activation patterns, when participants planned and executed these different grasps, we are therefore able to identify the brain regions involved in different stages of visual grasp selection.

Body Sway Induced by Oscillatory Optic Flow in Virtual Reality

David Engel, Adrian Schütz, Milosz Krala and Frank Bremmer
Department of Neurophysics, Center for Mind, Brain and Behavior, Philipps-Universität Marburg, Germany

In order to maintain balance, amongst other senses, humans heavily rely on vision. When subjects perceive their body as moving relative to the environment, they trigger counter movements, resulting in body sway. This sway is typically investigated in a real, moving room by monitoring the body's center of pressure (COP). Here, we aimed to (a) induce body sway by visually simulated self-motion in virtual reality (VR) and to (b) complement COP-measurements by markerless full body tracking. We simulated sinusoidal perturbations of the environment and quantified body sway of the subjects' COP and different joint positions in three-dimensional-space over time simultaneously. We found that subjects systematically adjusted their sway to the stimulus in a resonating fashion for a range of oscillatory frequencies. In addition, interindividual deviations were found for dynamics of specific body parts, suggesting sole COP tracking to be insufficient for functionally characterizing body sway.

Perceptual Judgements of Plaid Motions Biased by Active Movements

Giulia Sedda, Vittorio Sanguineti and Silvio Paolo Sabatini
Department of Informatics, Bioengineering, Robotics and Systems Engineering, University of Genoa, Italy

The interpretation of a plaid stimulus moving through an aperture is inherently ambiguous. It can be perceived either as a coherent pattern moving rigidly or as two gratings sliding over each other. Perceptual uncertainty thresholds can be modulated by changing the relative luminance properties of single gratings. Many studies on action-perception transfer suggested that information required by the motor system to produce movements affects visual motion perception. We reasoned that physical interaction between an observer and the stimulus may influence the perceptual uncertainty associated to the moving plaids. Accordingly, we designed a motor task in which observers actively generate the relative movement between the plaid and the aperture. A two-alternative forced choice task was performed before and after the motor task to assess the motor effect on the perception of plaid motion. Preliminary results show that action biases the perceptual decision in a wide range of conditions and with spatial differences.

Saccadic Adaptation Alters Object Size Perception

Alexandra Pressigout, Celine Paeye, Lara Kech and Karine Doré-Mazars
Department of Psychology, Paris Descartes University, France

Perceived object location is known to be correlated to motor changes in the oculomotor system. We investigate whether saccadic adaptation (the modification of saccadic amplitude) also affects object size perception. Participants compared the size of a test disk presented at saccadic target location, with the size of a standard disk presented after the saccade. Saccadic amplitude reduction was then induced by stepping the target during the saccade. Preliminary results showed a shift in psychometric functions after adaptation reflecting a decrease in perceived object size. Such a perceptual modification was not found when saccadic amplitude was not adapted (control group). These results add new evidence in favor of the link between oculomotor parameters and object perception. They will be discussed in the framework of a shared magnitude system for perception and action.

Impaired Sensory-Motor Learning in Newly Sighted Children

Sophia Pfister, Irene Senna, Dennis Wiebusch and Marc O. Ernst
Department of Applied Cognitive Psychology, Ulm University, Germany

Visual properties of an object, such as its size, influence its perceived weight and are used to predict the required fingertip forces for grasping. If visual estimates and actual object properties are in conflict like in the size-weight-illusion (SWI), the sensory-motor memory is updated such that grip forces are quickly scaled to the actual object weight, while the SWI persists perceptually. Would a person that had no visual experience so far scale grip forces correctly and fall for the SWI? We investigated a sample of previously blind Ethiopian children after

cataract removal when they were seeing for the first time. They lifted SWI-inducing cubes for several times, while grip forces were recorded. Participants did not change their force programming throughout the experiment, hinting to a failure to appropriately use vision for action. This suggests that vision without visual experience is not enough to make accurate predictions about object weight based on visual size information.

Should Priming, Prime Discrimination, and Prime Visibility Be Measured on the Same Trial? Loss of Double Dissociations Under Triple-Task Conditions

Thomas Schmidt and Melanie Biafora
Experimental Psychology Unit, TU Kaiserslautern, Germany

In masked priming experiments, speeded responses to the target, prime discrimination performance, and awareness ratings are sometimes measured within the same trial. We asked participants to discriminate masked shapes of primes and targets and to perform subjective visibility ratings under triple-task and single-task conditions at varying prime-target stimulus onset asynchronies (SOAs). In triple tasks, responses were about 150 milliseconds slower compared to single tasks. In the single-task condition, prime discrimination performance decreased while priming effects increased with SOA. This striking double dissociation was lost under triple-task conditions because prime discrimination now increased with SOA. We conclude that the requirements of triple-task performance cause massive cognitive costs that evoke qualitative changes in the effects, making it more difficult to detect evidence of unconscious perception.

Allocentric Information Influences Memory-Guided and Online Reaching Movements

Zijian Lu and Katja Fiehler
Department of Experimental Psychology, Justus-Liebig-University Giessen, Germany

We examined whether allocentric information influences not only memory guided but also online reaching movements. Participants viewed a breakfast scene with six objects on the table, which served as potential reach targets and landmarks. After scene encoding, participants were informed about the target object. We then applied a brief air-puff to the participant's eye, which induced an eye blink. During the blink, the target object disappeared, and the other five table objects were horizontally shifted in the same direction. After an auditory signal, participants reached toward the position of the target object. We varied the time of the air-puff, which occurred either before or at the signal (memory-guided reach), or after the start of the reaching movement (online reach). Our results demonstrate that the shift of landmarks (allocentric information) indeed influences participants' reaching end points in online reaching, although this influence is reduced compared to memory-guided reaching.

Investigating the Role of Vection for Quiet Standing in a Moving Room Paradigm With Sinusoidally Expanding and Contracting Visual Stimuli

Kentaro Horiuchi[1], Masami Ishihara[1] and Kuniyasu Imanaka[2]
[1]Department of Psychology, Tokyo Metropolitan University, Japan
[2]Department of Health Promotion Science, Tokyo Metropolitan University, Japan

Vision plays a major role in maintaining stable standing, and optical flow induced by expanding-contracting visual stimuli is known to affect postural sway. Vection, the visual illusion of self-motion, also affects postural control during dynamic visual stimuli simulating linear or rotating motion. However, few studies have studied vection with sinusoidally expanding-contracting visual stimuli. We have qualitatively measured vection, examined the dependence of vection and postural sway on the speed of the visual stimuli, and studied the relationship between postural sway and vection. Our results show that vection occurred primarily during rapidly moving visual stimuli, and that the magnitude of both vection and postural sway increased with the speed. However, we found no strong coupling between vection and postural sway within the stimulus speed conditions. This suggests that the presence of vection impacts neither postural control nor the role of optical flow in postural control.

Automatic Imitation Tendencies in Whole Body Movement With Balance Constraints

Tara Radovic
Department of Psychology and Ergonomics, Technische Universitaet Berlin, Germany

The aim of this study was to examine the influence of three categories of movement primes on foot lift execution in sitting and standing postures. At Max Planck Institute for Human Development, 36 participants did ideomotor priming task, where primes were (a) same as the task movement (foot lift), (b) superordinate (step

forward and step backward) that embed foot lift, and (c) subordinate (weight shift, artificial foot lift without weight shift) that are embedded in foot lift. Primes were neutral, congruent, or incongruent with lifting the right or the left foot. Interference effects in reaction time and errors were calculated as differences between incongruent and congruent situations for each prime. Compared to the foot lift prime, superordinate primes produced interference effects of the similar magnitude in both dependent variables, while subordinate produced significantly weaker effects. Results suggest stronger interference effects as the observed and the task movements share more action components.

Characterizing Brain Areas Activated During Well-Learned Versus Newly Learned Visuomotor Associations Using fMRI

Elizabeth Saccone[1], Sheila Crewther[1], Melvyn Goodale[2] and Philippe Chouinard[1]
[1]School of Psychology and Public Health, La Trobe University, Australia
[2]The Brain and Mind Institute, Western University, Canada

The current functional magnetic resonance imaging (fMRI) study identified brain regions implicated in performing well-learned versus new visuomotor associations. Stimuli were two sets of six abstract images, each paired arbitrarily with a unique hand gesture. Participants rehearsed one set of pairings over 4 days and learned the other set immediately prior to scanning. Preliminary data were obtained for four participants who demonstrated an average 106 milliseconds motor reaction time advantage when performing the well-learned associations prior to fMRI scanning. Regions-of-interest for the left and right lateral-occipital (LO) and the left anterior intra-parietal (AIP) areas were obtained by an independent functional localizer. Parameter estimates extracted from these regions demonstrate a greater blood oxygenation level-dependent response in right LO for new compared to well-learned associations, $t(3) = 7.59$, $p = .005$, but not left LO or AIP. Results suggest the right-hemisphere ventral stream is strongly activated before the automatization of visuomotor associations.

Sense of Agency in Joint Driving: The Collaboration Produces Good Performance

Sachiyo Ueda[1], Taku Maruoka[1], Atsushi Sato[2], Shoji Itakura[3] and Michiteru Kitazai[1]
[1]Department of Computer Science and Engineering, Toyohashi University of Technology, Japan
[2]Faculty of Human Development, University of Toyama, Japan
[3]Department of Psychology, Graduate School of Letters, Kyoto University, Japan

In everyday life, people often perform joint action with others to achieve a goal. The sense of agency over the collaborative work is important to accomplish the work, but it could be influenced by the co-actor. We set up the collaborative situation where two persons drove a car in various contribution ratios using a driving simulator and investigated how they estimated the own contribution to the driving. Participants were told that the contribution of their steering wheel operation reflected in driving was varied from trial to trial and asked to estimate the contribution ratio of their own operation after every trial. We found that their estimation generally corresponds to the actual value, but they estimated own contribution higher as the driving accuracy was higher. Even more interestingly, the driving accuracy was better when they were driving jointly than driving alone. These results suggest that the collaboration produces better performance.

Synesthetic Interference in Writing Letters

Seiji Oshiro, Hiroki Yamamoto and Jun Saiki
Graduate School of Human and Environmental Studies, Kyoto University, Japan

While grapheme-color synesthesia is known as a rare phenomenon about letter perception, letter production (writing aspect) of grapheme-color synesthetes has not been studied. We investigated effects of pen colors on synesthetes' letter writing to understand the relation between synesthesia and action. We hypothesized that in writing letters, their shape could be affected by the pen color incongruent with its synesthetic color. Synesthetes were asked to do a Stroop-like task in which they wrote a Japanese kana character repeatedly with a particular pen color during one trial. The synesthetes showed significant differences in the number of slips (miswriting) between the congruent and incongruent conditions, suggesting that the pen color affected the character's shapes. The strong grapheme-color ties in synesthetes modulate not only visual letter perception but also motor control in letter writing, which may have some implication of the bidirectionality of synesthesia.

Tracking Attention in Space and Time Around Saccadic Eye Movements

David Acunzo, Katya Gordienko and David Melcher
CIMeC, University of Trento, Italy

There is a longstanding debate over the overlap between covert attention and overt (saccadic) shifts. A classic finding is that attention is allocated at the saccadic target. Recent studies have shown fluctuations in perceptual threshold (behavioral oscillations) aligned to saccades either by measuring detection performance at presaccadic and then postsaccadic locations or at a third location. To map out the allocation of attention over space and time in a single study, we densely sampled detection at three locations over the whole trial: initial fixation, saccadic target, and third location. Prior to saccades, there were significant counterphase behavioral oscillations in hit rate between initial location and saccadic target location (2.5–2.8 Hz). After saccadic offset, the fluctuation were slower (around 1.5–1.7 Hz). These results challenge the idea of a simple link between spatial attention and saccades, showing that, aligned to saccades, multiple locations are sampled sequentially.

Effect of Speed Variability on Smooth Pursuit Eye Movement and Speed Perception

Kiana Mansour Pour[1], Laurent Perrinet[2], Anna Montagnini[2] and Guillaume S. Masson[2]
[1]Faculté de Médecine, Institute of Neuroscience of la Timone, France
[2]CNRS, Institut de Neurosciences de la Timone, France

Global speed estimation under complex naturalistic conditions is poorly understood. We investigated the effects of speed bandwidth (Bv) on smooth pursuit and speed perception in humans, using broadband random-texture stimuli (Motion Clouds [MC]) with continuous spatiotemporal frequency spectra. In the pursuit experiment, subjects tracked MC with different speed bandwidths (0.18–28.8 deg/s). Speed bandwidth non-linearly affected eye velocity: Above a cut-off value for the speed bandwidth of 3.6 deg/s, response amplitude decreased for increasing bandwidths. In a 2AFC speed discrimination experiment, participants had to compare the speed of a varying speed bandwidth test MC to that of a reference MC. This results shows that beyond that critical bandwidth (3.6 deg/s), the perception of coherent motion is impaired and subjects show a decreased performance. By increasing speed bandwidth, observers experience changing states of motion coherency and their ability to track global motion undergoes a corresponding deficit.

Kinematic Properties of Chopstick Manipulation When Grasping Sushi

Akira Hasegawa and Takao Fukui
Graduate School of System Design, Tokyo Metropolitan University, Japan

Although using chopsticks while eating is customary behavior for people in East Asia, few studies have examined the kinematic properties of chopstick manipulation. Here, we investigated the aperture adjustment by chopsticks or thumb and index finger. Right-handed participants who were familiar with manipulating chopsticks participated in three sequential sessions: first hand-grasping (PRE), chopstick action (CHP), and second hand-grasping (POST). In each session, the participants were required to reach for and grasp mockups of sushi (three sizes) using their fingers or chopsticks. The slope of the regression line between the peak grip (or chopstick tips') aperture and the mockups' size was calculated. We found that, in 12 out of 13 participants, the positive or negative sign of the POST-minus-PRE value corresponded with that of the CHP-minus-PRE value. These results suggest that short-term usage of chopsticks could influence subsequent hand-grasping even for frequent chopsticks users.

The Effect of A-Priori Size on Different Reach-to-Grasp Movements

Justin Plantier[1], Anne-Emmanuelle Priot[1] and Cyril Vienne[2]
[1]ACSO, IRBA, France
[2]Centre de Réalité Virtuelle, Groupe PSA, France

In many motor tasks, we do not know all features about an object we want to act upon. When the visual information is reduced, object size still plays a major role in distance perception, especially if object size is known. This study investigates whether varying size-distance relations of a three-dimensional object may affect distance, size and depth perception. Participants had to grasp virtual objects in three configurations: The index and thumb were used to estimate the width, depth and height of a virtual cylinder. Object size was either consistent with its distance or was retinally maintained constant. The results reveal that kinematics parameters were affected by the size condition. Object distance was misestimated when size was keep constant as revealed by larger amplitude and peak velocity of graping movements. Max grip aperture was also larger when retinal size was constant. Size thus may overtake disparity information for some observers, more attuned to prior information of object size.

Effect of Reward Value on Auditory Perception – An EEG Study

Felicia Pei-Hsin Cheng and Arezoo Pooresmaeili
Perception and Cognition Group, European Neuroscience Institute Göttingen, Germany

Reward biases perception but empirical evidence regarding whether such bias is pre-attentive or is mediated by attention has been mixed. The present study investigates the effect of reward on auditory perception and further elucidates the role of attention involved in auditory perceptual biases. In our experiment, participants learn to associate two reward values to two sounds that only differ in pitch. In separate blocks, sounds are presented in classical mismatch negativity (MMN) task as oddballs, and the MMN task is carried out with or without a demanding visual detection task. We will present the following results: (a) the comparison between the MMNs elicited by two different oddballs, which may be interpreted as a difference in reward-induced perceptual salience or reward prediction error, and (b) the possible effect of the visual task on the MMN difference, which may indicate that the magnitude of such perceptual bias can be modulated by different levels of attentional load.

Intent Perception of Human and Non-human Agent During Ball Throwing Task in Virtual Reality

Jindrich Kodl, Andrea Christensen, Tjeerd M. H. Dijkstra and Martin A. Giese
Department of Cognitive Neurology, Eberhard Karls University of Tübingen, Germany

Embodiment has been discussed as fundamental for the perception and control of body movements. Using a virtual reality setup, we studied how perception and performance during catching depends on body appearance of the thrower (human vs. robot). Movements of the virtual agent, presented using an HTC Vive head-mounted display, were derived from human underhand throws using motion capture. Hand and ball trajectories for both types of avatars were identical. Catching success was determined from the spatio-temporal error between ball trajectory and a key press on hand-operated sensor. In addition, subjective ratings about perceived naturalness of the avatars, immersion, and artefacts were assessed. We found strong learning effects for both avatar types, as catching performance increased with block number. Participants reported high levels of immersion, and catching was rated as easier for the human avatar, while this was not reflected in the catching performance.

The Phase of Intrinsic Gamma Oscillations Permit Visual Encoding

Emoke B. Ipkovich[1], Miha Medved[2], Jennifer Csatlos[1], Viktor Voros[1], Eszter Kormann[1], Szilvia Linnert[1] and Zoltan Nadasdy[3]
[1]Department of Cognitive Psychology, Eötvös Loránd University, Hungary
[2]Department of Cognitive Science, University of Ljubljana, Slovenia
[3]Department of Psychology, The University of Texas at Austin, TX, USA

To investigate the role of cortical oscillations (theta, alpha and gamma) in the selective processing of rapid visual information flow, we designed a rapid serial visual presentation (RSVP) paradigm and tested the phase modulation contingent on visual perception. After Hilbert transformation applied to the EEG of 22 subjects, we computed the average of phase profiles of correctly recognized and missed items. To obtain confidence estimates, we randomly shuffled the choices and calculated with confidence interval from simulations. Our results showed that largest gamma phase difference (GPD) was observed at the occipital and the occipital-frontal electrode positions and GPD emerged as early as stimulus onset, associated with the gamma band activity, and remained significant relative to both types of confidence estimates. Similar oscillation activity has been observed at the alpha suggesting that gamma provides a stimulus independent segmentation and filter of signal flow by setting a time window for visual information processing.

Learning and Combining Novel Perceptual Cues

Stacey Aston, Sophie Barnes, Ulrik Beierholm and Marko Nardini
Department of Psychology, Durham University, UK

Combining independent sensory cues allows for less variable estimates of world properties. With familiar cues, adults often show near-optimal combination, but this is not consistently observed in children, and it is unclear how this ability develops: Is repeated exposure to cues necessary or is the neural machinery yet to develop? In our task, adults learned to use novel cues to locate a school of fish along an axis, placing a net to catch them. Locations were signalled by the proportion of squares in a 10×10 grid that were black versus white (colour cue) or had a central piece missing (hollow cue). After 513 trials with each cue (in single and combined-cue conditions), 17 of 20 learned to use both cues. However, they gained only a small, non-significant, and non-optimal reduction in variable error with both cues compared to the best single cue ($p > .05$). With these two novel cues at least, optimal

combination is not immediate but may require longer experience.

Motion Silencing During Natural Movement

Simon Rushton[1], Laurence Harris[2], Geoffrey Mégardon[1] and Phoebe Asquith[1]
[1]Department of Psychology, Cardiff University, UK
[2]Centre for Vision Research, York University, Canada

When an array of flickering disks is moved, their perceived flicker reduces appreciably: a phenomenon known as motion silencing. Does motion-silencing occur when the movement of the disks is due to self-movement? A fixation point was surrounded by a ring of random-brightness disks. Observers detected where an embedded target disk changed in brightness in five conditions: (a) participants and stimuli stationary (control), (b) during head roll, (c) during stepping forwards, (d) during simulated head roll, and (e) during simulated stepping. The background was black or mid-grey. Self-movement increased detection thresholds (with perhaps a smaller increase during actual self-movement). Noticeably, thresholds were affected more by a change of background than by self-movement. We conclude that while motion silencing does occur during natural self-movement, the effect is small when seen in context.

Action-Induced Compression in the Perceived Time of Visual Events

Inci Ayhan and Duygu Ozbagci
Department of Psychology, Bogazici University, Turkey

Perceived duration of visual events are known to be changed by relevant modality-specific actions such as eye movements. Some activities such as driving, however, may require a rather action-linked multimodal calibration with the transient visual system. Here, we tested the effect of keypress on the perceived duration of visual events in a duration reproduction paradigm, where an array of dots accelerated (1–9 deg/s), decelerated (9–1 deg/s) or moved with a constant speed (5 deg/s) while participants were pressing a key. As a control, we also asked participants to reproduce the perceived time of the same visual events they generated in the visuo-motor condition, while this time in a pure visual condition. Results showed that, in all speed conditions, reproduced durations get compressed in the presence of an accompanying movement with respect to baseline values, providing further evidence for action-induced distortions in the perceived time of visual events.

Perception of Agent Properties in Humans and Machines

Erik Lagerstedt[1] and Serge Thill[2]
[1]School of Informatics, University of Skövde, Sweden
[2]Centre for Robotics and Neural Systems, Plymouth University, UK

Immediate and holistic perception of objects in terms of what function they have, or how they can assist the perceiver in achieving some goal, has a long history in research. Terms such as demand characters, functional tones and affordances have all been used to describe the perceived properties, but have acquired several, sometimes conflicting, meanings. However, they are generally used to discuss inanimate objects and tools. Here, we apply these concepts to the perception of agents to gain insights into the human ability to spot and predict general behaviours of surrounding animals (including humans). Such insights can, for example, inform the design of corresponding abilities for artificial systems and thus lead to safer environments with machines in close proximity to humans. Autonomous vehicles, for example, can apply this to the detection of vulnerable road users, in particular to perceive them in terms of their predicted behaviour.

Reviewing Evidence for Superior Visual Processing Without Awareness

Sascha Meyen, Iris Zerweck, Catarina Amado, Ulrike von Luxburg and Volker Franz
Department of Computer Science, University of Tübingen, Germany

Many studies found that humans are not visually aware of masked stimuli. When asked to discriminate them in a direct task, their performance is close to chance level. Nevertheless, the masked stimuli can affect indirect measures, for example, reaction times, skin conductance, or functional magnetic resonance imaging activity. This led to the interpretation that the prime is better processed (as indicated by indirect measures) than participants are aware of. We applied signal detection theory to reanalyze such findings from several highly influential studies. Surprisingly, direct task and indirect measures allow for the same discriminability of the masked stimulus in most of the studies. Such results are no evidence for better unconscious than conscious visual processing. Nevertheless, some studies survived our test. These studies used relatively simple visual stimuli. Therefore, we hypothesize that in simple stimuli, unconscious processing might be better than conscious processing.

Evaluating Methods in Visual Tasks: Confidence Ratings Convey More Information Than Binary Responses

Iris Zerweck, Sascha Meyen, Florian Friedrich, Klara Grethen and Volker Franz
Experimental Cognitive Science, University of Tuebingen, Germany

To investigate unconscious processing, researchers often present sequences of different stimuli (mask, prime, and target) and compare two tasks: In the direct task, participants directly respond to a masked prime. In the indirect task, participants respond to a target preceded by the masked prime. Typically, the prime has effects on reaction times in the indirect task, which is interpreted as preserved unconscious processing of the prime. However, this paradigm is problematic, because participants are restricted to a binary response in the direct task. Twelve participants gave a binary response and also judged their confidence on a continuous scale. We found that confidence modulated the accuracy of prime detection: Overall accuracy (mean $\pm$ *SEM*): 58.6%$\pm$1.4%; accuracy in high-/low-confidence trials: 64.4%$\pm$2.1%/53.5%$\pm$1.1%. We also applied classic information theory and found that the higher accuracies in high/low confidence trials increased the overall information about the prime.

Acoustic Noise of a Ship Cabin Affects Heart Rate Variability

Martina Lorenzino[1], Flavia D'Agostin[2], Giulia Scarinzi[3], Sara Rigutti[1], Luigi Bregant[3], Massimo Bovenzi[2] and Carlo Fantoni[1]
[1]Department of Life Sciences, University of Trieste, Italy
[2]Department of Medical Sciences, Clinical Unit of Occupational Medicine, University of Trieste, Italy
[3]Department of Engineering and Architecture, University of Trieste, Italy

Previous studies show that heart rate variability (HRV) mirrors the state of discomfort induced by different sources of environmental noise. It remains unclear whether HRV is affected by noise levels within the normal living range, and whether it reflects the mood state. We address this issue by evaluating the impact of acoustic noise levels experienced in a ship cabin on the HRV and asking participants to evaluate explicitly their mood state. Twenty-two subjects equipped with a digital Holter recorder, in a full-scale mock-up of a ship cabin, sat on a chair at rest in front of a mirror, keeping their eyes open. They were randomly exposed to ship cabin's five acoustic noise levels (30, 45, 47, 50, and 55 dB). HRV was significantly affected by the acoustic noise: It increased from 30 dB to 47 dB, reaching a plateau. This effect is evident for observers judging their mood as positive rather than negative. Acoustic comfort within normal living range affects HRV depending on internal mood state.

Control Re-Investment in the Execution of a Simple Sensorimotor Task

Valeria Gershkovich, Nadezhda Moroshkina and Almara Kulieva
Department of General Psychology, Saint Petersburg State University, Russia

Pressure-induced performance decrements ('Choking under pressure') is seen as either a problem of control re-investment or a distraction of attention. We tested the hypothesis that the structure of rewards (gains or losses) would induce either a promotion or a prevention of focus that in turn would affect the efficiency of task execution. In a virtual, golf-like scenario, players had to put the ball to a hole by pressing and holding a key for a certain period of time. We manipulated the distance to the targets and the amount of bonus or penalty. Group 1 participants were awarded with 5 points for each successful hit; Group 2 participants were penalized by 5 points for each unsuccessful hit. Pressure was induced by setting-up a competition between players. Group 1 participants made more mistakes when shooting for closer targets; conversely, Group 2 participants made more mistakes for the distant targets. Our results support the hypothesis of control re-investment. This study was funded by RFBR #16-06-00376.

Perceptual Organization

Perception of an Ambiguous Motion Display Is Not Shaped by Perceptual Relevance in an Auxiliary Task

Charlotte Boeykens, Pieter Moors and Johan Wagemans
Brain and Cognition, KU Leuven, Belgium

Perceptual organization (PO) can differ even when the stimulus information is the same. Previous studies have demonstrated the importance of previous experience and perceptual relevance in PO. We examined the influence of perceptual relevance on subsequent PO. Observers were presented with an ambiguous motion stimulus that could either be perceived as rotating dot-pairs (local) or pulsating geometrical figures (global). Prolonged perception of this stimulus is characterized by a shift to global, but it remains unclear whether this process is due to relevance of the global percept. During a

learning phase, participants were divided into conditions determining the relevant percept in an auxiliary task: active exposure, local, and global. In a pre- and post-test, individual points of subjective equality between local and global percepts were measured. Results indicate that there is indeed a shift to global. Interestingly, perceptual relevance did not seem to modify this process.

The Rapid Segmentation of Multiple Objects Is Based On Global Rather Than Local Sampling

Vladislav Khvostov, Igor Utochkin and Yulia Stakina
Department of Psychology, National Research University Higher School of Economics, Russia

We previously showed that people can discriminate multiple intermixed groups of objects based on "segmentability," large gaps between values in feature distributions forming several peaks. Here, we test whether such discrimination is based on local or global sampling. Two arrays of lines of various orientation (O) and length (L) were presented; both had identical feature distributions but opposite directions of O-L correlations. These sets consisted of either 14 lines near both meridians or 32 lines filling rectangular regions; participants had to determine boundary orientation between the sets with different O-L correlations. We found that displays with both O and L segmentable provide better discrimination than nonsegmentable ones and an advantage of 32-line sets. This suggests that the segmentation of spatially mixed objects is global sampling of lots of items based on full-scale feature statistics rather than local sampling near a potential boundary. This study was funded by RSCF #18-18-00334.

Induced Perceptual Organization in Ordered Dot-Lattices: The Effect of an Inclined Line

Arefe Sarami and Reza Afhami
Department of Arts, Tarbiat Modares University, Iran

The objective of this study was to investigate the effect of four types of tilted lines on grouping by proximity in square dot lattices oriented vertically horizontally: The tilted line was oriented near-vertical (26.5° ccw) or near-horizontal (63.5° cw) and it was either drawn explicitly or suggested implicitly by drawing additional dots in red in-between the lattice dots. The stimuli were shown to two groups of participants: 32 graduate art students and 23 high school students. Observers indicated if they saw a vertical or horizontal structure or any other structure in the dot lattice. Perception was clearly influenced in the direction of the inserted tilted line. There were no significant differences between explicit and implicit lines and between the groups of participants.

Grouping and 'Objecthood' Effects in the Ebbinghaus Illusion

Einat Rashal, Aline F. Cretenoud and Michael H. Herzog
SV-LPSY, EPFL, Switzerland

The Ebbinghaus illusion is argued to be a product of low-level contour interactions or a higher cognitive process. We examined the effect of mid-level grouping processes on the illusion by manipulating objecthood, that is, the degree to which an object is a cohesive entity. We presented observers with squares as targets and inducers and varied the degree of objecthood: (a) squares were composed of either corners or sides. Corners produce better squares than sides due to their collinearity; (b) gap size between object parts was varied, so that larger gaps produced less cohesive objects than smaller gaps. Participants adjusted the test target to match a control target in size. Our results show decreased illusion magnitude with increasing gap size. Also, overadjustment of target size was greater when the target was composed of sides compared with corners. These results suggest that mid-level processes affect the illusion; thus, it cannot be explained solely by low-level contour interactions.

A Prägnanz Framework of Perception

Eline Van Geert and Johan Wagemans
Laboratory of Experimental Psychology, Brain and Cognition, KU Leuven, Belgium

The law of Prägnanz states that "psychological organization will always be as 'good' as the prevailing conditions allow". What 'good' means, however, is not defined further. We clarify this definition by proposing that Prägnanz is about maximizing the efficiency of process and outcome. This includes both (a) spending minimal resources during the process of organization and (b) maximizing the usefulness (i.e., informativeness, functional relevance) of the organizational outcome. We propose a range of organizing principles, combining prior information (i.e., grouping laws, visual templates, and mental concepts) with the incoming visual input, that allow the viewer to come to the most prägnant percept possible under the current conditions (i. e., input, person, context, and their interactions). We will demonstrate that this view is compatible with hierarchical predictive coding theories of perception and we will discuss how to test it empirically.

Ventral Stream Hierarchy Underlying Perceptual Organization in Adolescents With Autism

Laurie-Anne Sapey-Triomphe[1], Bart Boets[2], Lien Van Eylen[2], Ilse Noens[3], Maarten Demeyer[1], Stefan Sunaert[4], Jean Steyaert[2] and Johan Wagemans[1]
[1]Brain and Cognition, Laboratory of Experimental Psychology, KU Leuven, Belgium
[2]Department of Neurosciences, Center for Developmental Psychiatry, KU Leuven, Belgium
[3]Parenting and Special Education Research Unit, KU Leuven, Belgium
[4]Department of Neurosciences, Translational MRI, KU Leuven, Belgium

Object recognition relies on a hierarchically organized ventral visual stream, with both bottom-up and top-down processes. The balance between these processes might be altered in autism spectrum disorders (ASD). Here, we aimed at investigating the neural mechanisms underlying perceptual organization in ASD. Typically developing adolescents ($n = 19$) and adolescents with ASD ($n = 19$) participated in a functional magnetic resonance imaging study. They had to detect objects in Gabor patterns evolving from random to organized, based on texture and contour. The groups did not show behavioural differences and the neural activity was generally very similar, extending from low-level occipital regions to higher level frontal regions. Yet, texture outline elicited less activity in the orbitofrontal cortex (OFC) in ASD. The OFC also showed less functional connectivity with high-level visual regions in ASD. As the OFC is involved in generating top-down predictions, ASD participants might integrate less top-down information.

The Event-Related Potential Time Course of Adaptation to Contours and Textures

Damien Wright[1], Jasna Martinovic[2] and Elena Gheorghiu[1]
[1]Department of Psychology, University of Stirling, UK
[2]School of Psychology, University of Aberdeen, UK

Here, we examine the event-related potentials (ERP) signature and time course of neural processes involved in contour-shape and texture-shape coding following adaptation to assimilations and segregations of contours into and from surround textures. We used first-order ('snake') and second-order ('ladder') contour and texture adaptors and tests. We found that the ERP difference wave between pre- and post-adaptation to contours and textures: (a) snake contour-tests showed an early component (~150 milliseconds) that depended on the adaptor type and a late component (~250–500 milliseconds) that was independent of the adaptor; (b) for ladder contour-tests, the opposite effects were found. (c) For texture tests, both early and late components were positive for contours and negative for texture adaptors. We conclude that the ERP components reflect different processes involved in adaptation to textures and contours, when presented in isolation and in context as assimilated or segregated from surround textures.

Perceptual Organization of Hierarchical Patterns: Grouping Local Elements Into a Global Configuration Requires Visual Consciousness

Shahar Sabary, Dina Devyatko and Ruth Kimchi
Department of Psychology, University of Haifa, Israel

We examined whether organization of local elements into a global configuration can occur in the absence of visual consciousness, using a priming paradigm and sandwich masking to render the prime invisible. The prime consisted of a hierarchical pattern, and the target could be congruent or incongruent with the global or the local level of the prime. On each trial, participants made speeded discrimination of the target and then rated the visibility of the prime using a scale ranging from 0 (*I saw nothing*) to 3 (*I clearly saw*). Significant response priming of the local elements, but not of the global configuration, was observed when the prime was reported invisible. In visible trials, there was a significant response priming only of the global configuration, indicating global dominance typically observed with hierarchical patterns in the presence of awareness. These findings suggest that visual awareness is essential for the organization of local elements into a global configuration.

Comparing the Perception of Rectangular and Parallel Contours

Ekaterina Koshmanova and Tadamasa Sawada
School of Psychology, National Research University Higher School of Economics, Russia

The perception of a pair of contours in a retinal image is different from the sum of the perceptions of the individual contours, especially when they form a rectangular junction, or are parallel to one another. It is hard to actually compare the perception of these configurations quantitatively. We did this in this study, by testing the perception of such configurations in three psychophysical experiments in which the perception was characterized by using an

orientation threshold of a single contour. This threshold was estimated by using a modified Method of Constant Stimuli based on the assumption that contours forming a configuration are perceived individually. It makes the quantitative comparison of the perceived configurations possible. The estimated threshold is smaller for a rectangular junction and for parallel contours than for a single contour. The results suggest that the visual system is sensitive to rectangular junctions and parallel contours in a retinal image.

Fast Periodic Visual Stimulation Electroencephalography as a Measure for Perceptual Discrimination and Categorization

Jaana Van Overwalle[1], Charlotte Buhre[1], Stephanie Van der Donck[2], Sander Van de Cruys[1], Bart Boets[2] and Johan Wagemans[1]
[1]Brain & Cognition, KU Leuven, Belgium
[2]Center for Developmental Psychiatry, KU Leuven, Belgium

The ability to discriminate and categorize things is crucial to interact efficiently with the world. Thus far, discrimination and categorization have mainly been investigated in explicit tasks, possibly giving rise to decisional or motivational biases. Therefore, a more direct and implicit neural index of perceptual discrimination and categorization is needed. We believe that Fast Periodic Visual Stimulation (FPVS) during scalp electroencephalography (EEG) provides that. In FPVS, visual stimulation of the brain at a constant frequency rate leads to an EEG response at that exact frequency. Our data suggest that the FPVS sweep paradigm is able to implicitly detect a switch in categorical perception. Next, we will investigate whether the FPVS oddball paradigm enables an implicit discrimination measure, and whether these neural signatures of low-level discrimination and high-level categorization can be linked to levels in the visual cortical hierarchy and to individual differences in behavioral processing.

The Adaptation Aftereffect of Mean Size Precedes Size-Distance Rescaling

Natalia Tiurina[1], Yuri Markov[1], Jennifer Corbett[2] and Igor Utochkin[1]
[1]Department of Psychology, National Research University Higher School of Economics, Russia
[2]Department of Psychology & Centre for Cognitive Neuroscience, Brunel University, UK

The adaptation aftereffect (AAE) of mean size suggests that mean size is coded as a basic visual property. Also, size-distance rescaling of individual objects occurs prior to averaging. Because it is unclear whether the AAE is based on rescaled mean size, we tested the degree of AAE as a function the apparent mean size of stimuli presented at different depths. Observers were stereoscopically shown an adapting patch of dots with either a large or small mean size, followed by a brief test circle. Adaptors and tests were presented at a near and a far plane, both in the same or in different planes. Observers then adjusted the size of a probe in the middle plane to match the test size. We found evidence of the AAE and for test size rescaling, but no effect of whether the adaptor and test were presented in the same or in different planes. Our results suggest that the AAE of mean size take places at a lower level of visual processing than size-distance rescaling. This study was funded by RFBR #18-313-00253.

Reevaluating hMT+ and hV4 Functional Connectivity Using fMRI-Guided rTMS

Kathy Mullen and Daniel B. Cohen
Department of Ophthalmology, McGill University, Canada

Although hMT+ and hV4 are thought to be modular areas within the dorsal and ventral streams, there is evidence to support functional overlap between them. Here, we use functional magnetic resonance imaging (fMRI)-guided repetitive transcranial magnetic stimulation (rTMS) to explore this cross-functionality. We assess performance on four variations of a global discrimination task: two motion-based tasks (direction and speed) and two static, form-based tasks (orientation and contrast), presented in both ipsilateral visual field (IVF) and contralateral visual field (CVF). rTMS of both hMT+ and hV4 impairs the motion discrimination tasks. The hMT+ effects occur in both visual fields whereas the hV4 effects are only found in the CVF. Contrast discrimination is impaired by stimulation of hMT+ and hV4 but only in the CVF. Orientation discrimination is not affected. We conclude that (a) hMT+ has a bilateral visual field representation for motion tasks, and (b) the impairment of motion and contrast discrimination in hV4 supports a functional convergence between these two areas.

Does Spatial Uncertainty Affect Perception of Ensemble Statistics?

Vasilii Marshev[1], Andrey Chetverikov[2] and Maria Kuvaldina[3]
[1]Optics Department, IMT Atlantique, France
[2]Donders Institute for Brain, Cognition and Behaviour, Radboud University, the Netherlands
[3]Department of Psychology, Farmingdale State College, NY, USA

In two experiments, we tested if observers would estimate orientation statistics from a set of stimuli more precisely if stimuli are arranged in a simple pattern rather than positioned randomly. We used an explicit and an implicit procedures to test the effect of spatial organization. With the explicit procedure, observers judged the average orientation of a set of lines in a 4-AFC task. With the implicit procedure, we tested how well participants can learn the distribution of distractors' orientation in an odd-one-out visual search. Preliminary results suggest that spatial uncertainty does not affect explicit judgments but might affect the representation of orientation distribution obtained with implicit procedure.

Peripheral Vision

Emergence of a Hierarchical Structure in the Neural Representation of Visual Objects in the Rat

Eis Annavini, Mattia D'Andola and Davide Zoccolan
Cognitive Neuroscience, SISSA, Italy

Rats are gaining prominence as models of the mammalian visual system, thanks to their experimental accessibility. Recent works have shown their ability to invariantly recognize visual objects undergoing identity-preserving transformations. Neurophysiological measures suggested that the low-level information is progressively skimmed while moving upwards in their visual hierarchy. To investigate more in depth such organization in terms of neural representations of visual objects, we recorded the neural activity from rat primary visual cortex and three extrastriate areas during passive visual exposure to a rich stimulus set designed to explore a large space of visual features and transformations. The neural activations were characterized through clustering, dimensionality reduction and information theory techniques, revealing a progressive increase in the complexity of the visual features processed along the visual pathway.

Encoding Perceptual Ensembles During Visual Search in Peripheral Vision

Daglar Tanrikulu[1], Andrey Chetverikov[2] and Árni Kristjánsson[1]
[1]Department of Psychology, University of Iceland, Iceland
[2]Center for Cognitive Neuroimaging, Donders Institute for Brain, Cognition and Behavior, the Netherlands

Observers can learn complex statistical properties of visual ensembles, such as the shape of their underlying distributions. Even though ensemble encoding is critical for peripheral vision, distribution shape learning in the periphery has not been studied. Here, we investigated this using a visual search task, in which observers looked for an oddly oriented bar among distractors taken from either uniform or Gaussian orientation distributions with the same mean and range. The search array was presented either in the foveal or peripheral visual field. Surprisingly, our results indicated that search performance was better in the periphery, but little, or no distribution learning effects were observed across display locations, possibly because the search arrays were presented briefly (250 milliseconds) to prevent eye movements. Given the importance of crowding and texture perception for peripheral vision, these results suggest an interesting interaction between those and ensemble encoding.

Auditory Cue Suppresses Visual Detection in Extreme-Periphery

Takashi Suegami[1,2], Daw-An Wu[2], Mark Changizi[3] and Shinsuke Shimojo[1,2]
[1]Advanced Technology Research Division, Yamaha Motor Corporation USA, CA, USA
[2]Division of Biology and Biological Engineering, California Institute of Technology, CA, USA
[3]2AI Labs, ID, USA

Several studies found cross-modal cueing can enhance perceptual tasks; visual stimulus, for example, can be better detected with auditory cue than without it. Most studies, however, focused on a target within foveal or peripheral visual field (e.g., 20°–50° eccentricity). Neurological and behavioral studies showed auditory can complement visual perception in the periphery, but such cross-modal cueing in the extreme-periphery has been unexplored. In the present study, participants detected a dot appeared randomly in either left/right extreme-periphery (from 60° to 90°, with 5° distance). In a half of the trials, the dot was presented with a simultaneous beep as an auditory cue. The results counterintuitively indicated that auditory cue significantly decreased the visual detection in the extreme-periphery. Further pilot study implied auditory cue may be more reckoned on with widespread visual attention and produced false alarms, resulting decreased sensitivity in the extreme-periphery.

Local Diascleral Light Stimulation of the Peripheral Retina: Influence on Colour Perception in the Foveal Area

Alexander Belokopytov, Svetlana Rychkova, Galina Rozhkova and Maria Gracheva
Lab 11 – Vision Systems, Institute for Information Transmission Problems (Kharkevich Institute) – IITP RAS, Russia

Our aim was to obtain some quantitative data on changes in foveal colour hue recognition caused by diascleral local light stimuli that were invisible or visible depending on the stimulus location on blind or sighting retina. Ambient illumination was 300 lx. Foveal test stimuli of varying size and colour were taken from Rabkin. Parameters of the scleral stimuli in all locations were identical (1 × 3 mm, 20,000 lx). The subjects were six adolescents aged 14 to 18 years. It was found that, in the cases of small size and low saturation, invisible peripheral diascleral stimuli exerted significantly larger effects than more central visible stimuli. After invisible stimulation of peripheral retina, the number of right responses could fall to zero while visible stimuli had no effect. Our data evidence in favor of Yarbus's idea of specific role that peripheral blind retina could play in visual perception but only in the range of weak visual stimuli. This study is supported by RFBR grant 16-04-01421a.

Local Diascleral Light Stimulation of the Peripheral Retina: Influence on Contrast Sensitivity in the Foveal Area

Maria Gracheva, Svetlana Rychkova and Galina Rozhkova
Lab 11 – Vision Systems, Institute for Information Transmission Problems (Kharkevich Institute) – IITP RAS, Russia

To verify Yarbus's idea of specific role of the peripheral blind retina in visual perception, we compared the changes in foveal contrast sensitivity caused by diascleral light stimuli (1 × 3 mm, 20,000 lx) of the loci at the extreme periphery (supposedly blind retina) and in the mid-periphery (sighting retina). Ambient illumination was about 300 lx. Foveal tests were gratings 0.5 to 16 cpd with contrast 1% to 35%. To exclude influence of a possible difference in the two diascleral stimulus intensity on the results, pairs of the loci in the nasal and temporal halves of the retina were chosen so that they provided equal pupillary responses. Subjects were six adolescents aged 14 to 18 years. We found that the peripheral diascleral stimuli exerted significantly larger effects: In the range of spatial frequencies 1 to 4 cpd, foveal contrast thresholds typically increased 8 times after stimulation of the peripheral retina and only 3 times in the case of the mid-peripheral retina. This study is supported by RFBR grant 16-04-01421a.

Local Diascleral Stimulation of the Peripheral Retina: Influence on Pupillary Responses

Svetlana Rychkova and Maria Gracheva
Lab 11 – Vision Systems, Institute for Information Transmission Problems (Kharkevich Institute) – IITP RAS, Russia

To study functions of the far peripheral retina, pupillary responses to diascleral light stimulation were measured at different stimulus positions along the retinal horizontal meridian in nine subjects (14–27 years). A stimulus was a small light spot (1 × 3 mm, 2 × 105 lx) projected onto the eye surface at five positions: at the canthus, $1/4$, $1/2$, and $3/4$ of the distance from the canthus to the limbus, and at the limbus. Maxima of the pupil contraction were observed at positions $1/4$ and $3/4$. The stimulation near the limbus did not change pupil size. The reasons for the non-monotonic changes of the pupil contraction with changing stimulus position on the eye surface could be both anatomical and functional: differences in thickness and structure of tissues between eye surface and the retina, neuronal organization of the pupillary responses, and so on. Taking this complexity into account is essential for interpretation of the outcomes of diascleral stimulation experiments. This study is supported by RFBR grant 16-04-01421_a.

Inhibition of Return at the Visual Field Periphery

Gleb Laskov, Polina Krivykh and Galina Menshikova
Department of Psychology, Lomonosov Moscow State University, Russia

Bao and Pöppel investigated features of attention distribution in foveal and peripheral regions (up to 35°) focusing on inhibition of return phenomenon. In our study, we used a multiple cueing approach to investigate whether location inhibitory effects and inhibition of return are still present in the expanded peripheral regions. Stimuli were presented in the CAVE virtual reality at various eccentricities: 10°, 15°, 20°, 30°, 35°, 40°, and 45°. The subjects (5 males and 12 females) focused on the central fixation cross and reacted to the stimulus appearance by pressing the joystick button. We registered reaction time and head deviations when target or cue presented. Our results demonstrate that reaction time systematically increases on higher eccentricities both for cued and uncued locations, dramatically after 20°. Head tracking results revealed that head deviations are insignificant but correlate with values of eccentricities.

Peripheral Vision Loss Affects the Processing of Spatial Frequency in the Central Vision of People With Glaucoma

Audrey Trouilloud[1], Alexia Roux-Sibilon[1], Foriane Rutgé[2], Louise Kauffmann[3], Arnaud Attyé[4], Christophe Chiquet[5], Florent Aptel[5] and Carole Peyrin[1]
[1]Department of Psychology, University Grenoble Alpes, CNRS, LPNC, France
[2]Department of Ophthalmology, Grenoble University Hospital, France
[3]Images-Signal, University Grenoble Alpes, CNRS, Grenoble INP, GIPSA-Lab, France
[4]Department of Neuroradiology and MRI, University Grenoble Alpes, Inserm US 17, CNRS UMS 3552, France
[5]Department of Ophthalmology, University Grenoble Alpes, Inserm, France

Glaucoma is an ocular disease characterized by a progressive vision loss starting with a deficit in peripheral vision. However, there is recent evidence of visual deficits even in the central vision of patients with glaucoma. We assessed the spatial frequency processing in the central vision of glaucomatous patients during scene categorization. Since glaucoma affects neurons with larger cell bodies early in the disease, we hypothesized early selective impairments for processing low spatial frequencies. Patients and age-matched controls were asked to categorize low-pass or high-pass filtered scene images presented in central vision. Results showed that patients classified as having early visual field defect had a selective deficit for low-pass filtered scenes, while patients with a more severe glaucoma were impaired in all spatial frequencies. The simple loss of peripheral vision could be detrimental to scene recognition in the relatively preserved central vision of patients.

A New Approach to Investigate Peripheral Vision: Contact Lens With Opaque Central Part

Galina Rozhkova[1], Olga Selina[2], Petr Nikolaev[1] and Alexander Belokopytov[1]
[1]Lab 11 – Vision Systems, Institute for Information Transmission Problems (Kharkevich Institute) – IITP RAS, Russia
[2]Department of Contact Lens Correction, Helmholtz Research Institute of Eye Diseases, Russia

A typical paradigm for studying peripheral vision implies simultaneous presentation of peripheral test stimulus and of central fixation target to prevent involuntary turn of the eye to the peripheral stimulus. Such conditions require splitting attention between the central and peripheral stimuli thus hindering investigation of peripheral vision per se. To overcome this hindrance, we have developed an approach based on earlier attempts of Rozhkova and Yarbus to study isolated peripheral vision by means of a suction cap with opaque lid for central part. Now we employed a contact lens with opaque area in the center. Preliminary experiments demonstrated significant benefits of this technique for studying peripheral vision capabilities. At the same time, specific conditions of viewing through our lens and eye fixation could evoke some phenomena not observed in the case of usual paradigm and could complicate the analysis of experimental findings. This study is supported by RFBR grant 16-04-01421a.

Scale-Invariance for Radial Frequency Patterns in Peripheral Vision

Anna Zolubak, Gunnar Schmidtmann and Luis Garcia Suarez
School of Health Professions, Plymouth University, UK

Radial frequency (RF) patterns are sinusoidally modulated contours. Previous studies have shown that RF shape discrimination (RF vs. circle) is scale-invariant, that is, performance is independent of radius size when presented centrally. This study aims to investigate scale-invariance in peripheral vision (0°–20° nasal visual field, radius 1°, RF = 6, SF = 1 or 5 cpd) by scaling radii according to the Cortical Magnification Factor (CMF) and its fractions (MF1 = $1/2$, MF2 = $1/4$, MF3 = $1/8$). Results show that performance remains constant with eccentricity for CMF, MF1, MF2 and for two observers ($N = 4$) for MF3. However, the average performance for MF2 was twice and for MF3 4 times worse compared to CMF and MF1. The scale-invariance found for larger stimuli indicates the involvement of global shape processing in the periphery. The higher, yet constant thresholds for smaller patterns suggest that the resolvability of the contours limits peripheral performance and may elicit processing by low-level mechanisms.

Compression and Expansion Effects for the Perception of Dot Textures in the Peripheral Vision

Masahiko Terao[1] and Fuminori Ono[2]
[1]Research Institute of Time Studies, Yamaguchi University, Japan
[2]Department of Education, Yamaguchi University, Japan

Adaptation to dot texture makes a dot texture appear sparser but reduces the apparent separation of two objects or size of an object. This suggests that computation of texture density shares mechanism underlying computation of visual space. Here, we report similar paradoxical situation without adaptation to dot texture. When we presented two objects in the peripheral, apparent separation of two objects was compressed. On the other hand, when we presented dot texture in the peripheral, apparent dot texture became sparser while at the same time

texture area appeared compressed. This expansion consists with a report that apparent numerosity is reduced in the peripheral. It is known that the number of neurons at the early stage dedicated for the peripheral vision is far fewer than those for central vision. Our findings suggest that this space-variant sampling may affect perception of spatial relationship, such as texture or visual space.

Looking Versus Seeing, Peripheral Versus Central Vision, and Top-Down Feedback From Higher to Lower Visual Areas

Li Zhaoping
Department of Computer Science, University College London, UK

Looking selects a fraction of visual inputs for the attentional bottleneck; seeing recognizes the objects in the selected inputs, typically brought by eye movements from peripheral to central visual field. Hence, peripheral and central vision are better at looking and seeing, respectively. Zhaoping hypothesized that, using analysis-by-synthesis for better object recognition (seeing), top-down feedback from higher cortical areas to the primary visual cortex (V1) is weaker or absent in peripheral visual field. Accordingly, peripheral vision is more easily fooled by feedforward inputs from V1, is more prone to illusions and vulnerable to crowding, and conveys mainly ensemble or summary input statistics. For example, V1 neurons respond to binocularly anti-correlated random-dot stereograms as if the input binocular disparities reversed their signs; peripheral but not central vision perceives the reversed depths in such stereograms.

Research Methods

Water Consumption Estimation in Adults and Children: An Innovative Experimental Approach

Ilaria Santoro, Sandra Pellizzoni and Tiziano Agostini
Department of Life Sciences, University of Trieste, Italy

Recent research considers consumers' behavior and beliefs as fundamental elements in the promotion of environmentally sustainable consumption of natural resources, focusing on consumers' perception of water consumption. By employing surveys and analysis of household actual consumption, several studies suggested that people are not aware of the volume of water consumed daily. We aimed at investigating water consumption estimation by using an innovative approach which focused on the individual perception of the sensorial experience related to water flow. In particular, we examined whether adults and children were able to estimate the volume of water supplied by a domestic tap. Our outcomes showed a different pattern of results for adults and children as for water consumption estimation, suggesting the existence of a kind of bias in the perception of the sensorial experience of water flow.

The Theoretic-Scientific Evolution of the Milan and Trieste Psychology Schools

Walter Coppola[1], Savina Raynaud[2] and Serena Cattaruzza[1]
[1]Department of Life Sciences, University of Trieste, Italy
[2]Department of Philosophy, Università Cattolica del Sacro Cuore, Italy

Agostino Gemelli – founder of the Catholic University of the Sacred Heart in Milan – and Gaetano Kanizsa – initiator of the Institute of Psychology in Trieste – share a particularly personal and scientific connection with Cesare Musatti, who was a student of Vittorio Benussi. The topics developed by Gemelli in Milan were mainly experimental phonetics and psychology of thought and language. However, the contribution made in the field of perception by Musatti was original and relevant as well. The Trieste school, instead, was a typical expression of the Italian Gestalt tradition, developing research in the areas of visual perception (shape, colour and movement) and, more generally, in the field of vision science. The present work outlines the path of the theoretic–scientific evolution of these Schools, highlighting the works of the scholars and their students who, from different perspectives, experimentally investigated the nature of mental and perceptual experiences.

What Does Affect Serial Dependence in Visual Perception?

Debora Stendardi[1], Martina Lorenzino[2], Rosita Liperoti[1], Ilaria Colpizzi[1], Joseph Austerweil[3] and Corrado Caudek[1]
[1]NEUROFARBA, University of Florence, Italy
[2]Department of Life Sciences, University of Trieste, Italy
[3]Department of Psychology, University of Wisconsin-Madison, MI, USA

Is serial dependence in visual perception (i.e., the perceptual distortion of the current stimulus in the direction of the just-seen stimulus) an adaptive phenomenon or an obstacle to optimal visual processing? The current literature assigns an adaptive role to the serial dependence

phenomenon, although such argument is mostly theoretical with few supporting empirical evidence. In a series of experiments, we dealt with this question in a Bayesian framework by varying the reliability of the current stimulus. Our main manipulation concerned the attentional focus (narrow focus: high reliability; broad focus: low reliability). We predicted that the magnitude of the serial dependence bias would be inversely related to the reliability of the current visual information. Our results strongly support the adaptive role of serial dependence by showing that the magnitude of the perceptual bias is inversely related to the level of uncertainty associated with the current information.

Post-Hoc Trial Sorting Revisited: Comparing the Statistical Outcomes of Repeated-Measures ANOVA and Linear Mixed Models in Unbalanced Data Sets

Guido Hesselmann
Department of Psychiatry & Psychotherapy, Charité
Berlin, Germany

Within-participant designs are widely used in perception research, often in combination with post-hoc trial sorting (e.g., based on subjective stimulus visibility). Linear mixed models (LMMs) are sometimes preferred over repeated measures ANOVA (rm-ANOVA) only for their ability to better deal with unbalanced data sets. We simulated response times (RTs) to a visible target stimulus as a function of the visibility of a peri-liminal cue stimulus. Our results show that LMMs yield more false positives than rm-ANOVA in the case of heavily unbalanced data sets, when a relationship between RTs and visibility ratings remained unaccounted for in the analysis. We will validate this finding by applying LMMs to openly available within-participant data sets from published studies and discuss a number of simple remedies. We conclude that researchers using LMMs specifically for unbalanced within-participant data sets should be aware of the potential pitfalls described in our study.

Psychophysics Toolbox for Virtual Reality

Aman Mathur[1], Rupak Majumdar[1] and Tandra Ghose[2]
[1]RSE, Max Planck Institute for Software Systems, Germany
[2]Department of Psychology, University of Kaiserslautern, Germany

Virtual Reality (VR) presents unique opportunities for perception research. However, creating such experiments has been difficult due to unintuitive low-level programming interfaces and rapidly changing technology. We describe Psychophysics Toolbox for Virtual Reality (ptvr), an open-source high-level software interface on top of VR devices for perception experiments. ptvr provides a Python-based scripting interface similar to PsychoPy but for VR experiment design, for example, on HTC Vive. ptvr offers a high-level interface for placing objects in three-dimensional space, getting input from hand controllers, and timing mechanisms for creating appropriate trials, freeing the experimenter from low-level graphics, device access, and event handling issues. ptvr also provides useful components such as fixation scenes to help participants reorient themselves inside the virtual world and response scenes to pose questions and record participant answers. We have used ptvr to design a number of visual perception experiments in VR.

Steady-State Visual-Evoked Potentials in Oculocutaneous Albinism

Diána Fülöp, Eszter Mikó-Baráth, Vanda Nemes, János Radó and Gábor Jandó
Institute of Physiology, University of Pécs, Hungary

Oculocutaneous albinism (OCA) is a genetic disorder of melanin synthesis, which affects the development of visual pathways and the retina. The visual symptoms include nystagmus, severely reduced visual acuity, and lack of stereopsis. Abnormal routing of the optic nerve fibers results a contralateral predominance to monocular visual stimulation. In this study, flash and pattern onset checkerboard steady-state visual-evoked potentials (SSVEP) were recorded to monocular stimulation at different stimulus frequency. Two subjects were involved in this study: a child with OCA (8 years old) and a healthy subject as a control. T2circ statistic ($p = .01$) was used to analyze the SSVEP responses in the occipital areas. In the healthy child, phase difference could not be observed between the two hemispheres, while in the albino patient an obvious phase shift was found, referring to interhemispheric asymmetry. In conclusion, the SSVEP is an appropriate method to identify optic nerve misrouting in OCA.

Searchlight Back-Projection – A Tool for Analyzing Neural Signatures in Visual Space

Susanne Stoll[1], Elisa Infanti[1] and D. Samuel Schwarzkopf[2]
[1]UCL Experimental Psychology, University College London, UK
[2]School of Optometry and Vision Science, The University of Auckland & UCL Experimental Psychology, University College London, UK

Population receptive fields (pRFs) can be used to back-project brain activity into visual space. Usually, this involves summation of Gaussians, producing overly blurry back-projections. Here, we present a novel approach enabling greater spatial precision. Using functional magnetic resonance imaging, we mapped participants' pRFs and measured responses to peripheral visual stimuli. For back-projection, we passed a searchlight through visual space and gradually averaged responses of pRFs with centers in this searchlight. We found that relative to a fixation baseline, activity increased in stimulated and decreased in non-stimulated sites in both early and late visual areas. Moreover, our observed back-projections always correlated most strongly with predicted back-projections of the original stimuli relative to position-shifted variations. Our approach seems thus ideally suited for quantifying and decoding neural signatures of various visual phenomena, such as imagery or illusory percepts.

May the Power Be With You: Pilot Data-Based Simulations for Estimating Power in Mixed Models

Leah Kumle, Dejan Draschkow and Melissa L.-H. Vo
Department of Psychology, Goethe University Frankfurt, Germany

There has been a strong surge for sufficient power and precision in confirmatory analyses, for example, JEP:HPP now has sample justification as a standard submission requirement. Estimating the power and planning the study's sample size are important for reliability, replicability, and interpretation also in studies of visual cognition. Although there is a range of analytic power equations to address this issue, they are not suitable and flexible enough for more complex experimental designs and data analyses such as mixed models. Furthermore, power analysis is based on an estimate, theoretical or empirical, of effect size, which is often difficult to justify. We propose estimating adjusted effect size using simulation on independently sampled pilot data. These data can be used as the basis for a pre-registration and inform needed sample size as well as required analysis steps. Here, we provide an easy-to-adapt pipeline in R which can grow with input not only from the vision science community.

Optimizing the Number of Visual Presentations for Time-Resolved Decoding Studies

David Tovar[1], Tijl Grootswagers[2], Amanda Robinson[2], Mark Wallace[3] and Thomas Carlson[2]
[1]Department of Neuroscience, Vanderbilt University, TN, USA
[2]Department of Psychology, University of Sydney, Australia
[3]Department of Hearing and Speech Sciences, Vanderbilt University, TN, USA

Temporal decoding methods are becoming increasingly popular for their ability to elucidate the time course of cognitive processes and generalize neural activity between stimuli, time, and conditions for EEG and MEG studies. In this emerging area of research, efforts to characterize the effects of preprocessing and analysis choices have been informative, but experimental design questions such as how many stimulus presentations are required to reliably detect an effect remain unanswered. To study this, we used existing data sets from published MEG and EEG studies and replicated the study findings. We studied decoding onset and peak decoding as a function of the number of trials used for the analysis. For all studies, we found that the number of trials could be reduced without affecting the estimate of decoding onset or peak decoding. These findings provide a possible method that can be applied to pilot data to significantly reduce study times and improve efficiency.

Add-On Gamification Might Help to Increase Participants' Motivation, but Not Evidently Their Performance in a Visual Color-Matching Task

Marius Raab, Antonie Burmester, Claus-Christian Carbon and Alexander Pastukhov
Department of General Psychology and Methodology, University of Bamberg, Germany

The implementation of game elements in non-game contexts (gamification) is widely discussed as universal instrument to increase motivation and guide behaviour. We evaluated the suitability of points, badges and leader boards to improve behavioural response and motivation in a psychological experiment: An attention-demanding perception-reaction task with motoric response where coloured circles had to be cue-matched. Results ($N = 28$) showed that overall, there is no significant effect of basic game elements on visual-behavioural response and motivation. If anything, gamification tended to negatively affect performance while positively influencing intrinsic motivation, with both effects remaining non-significant. While gaming habits showed no influence on the effect of gamification, participants with stronger gaming habits had a faster

reaction time in general. Results are discussed within implications for the usefulness of game design elements in psycho-physical research.

Evaluating Linear Systems Theory for Sub-Millimetre Laminar fMRI

Jelle van Dijk[1], Alessio Fracasso[2], Natalia Petridou[3] and Serge Dumoulin[4]
[1]Department of Experimental Psychology, Utrecht University, the Netherlands
[2]Institute of Neuroscience and Psychology, University of Glasgow, UK
[3]Department of Radiology, Rudolf Magnus Institute of Neuroscience, University Medical Center Utrecht, the Netherlands
[4]Spinoza Centre for Neuroimaging, the Netherlands

A fundamental assumption of nearly all functional magnetic resonance imaging (fMRI) analysis methods is that the relationship between local neuronal activity and the fMRI signal follows linear system theory, that is, increases in neural activity cause proportional increases in fMRI signal amplitude. These assumptions are validated for conventional resolutions (>1 mm isotropic) but not for sub-millimetre laminar fMRI. Ultra-high field MRI (7T) allows for laminar imaging, that is, measuring responses across the cortical thickness. However, known vasculature relationships across lamina strongly affect the signal and may affect the linearity assumptions. Here, we tested the basic assumptions of linear systems theory in V1, V2, and V3 at sub-millimetre isotropic resolution using 7T MRI. We evaluated whether fMRI response amplitudes were proportional across stimulus intensity and duration. We find that the assumptions for linear system theory hold and can be applied for sub-millimetre laminar fMRI.

Gender Differences in Interpersonal Distances During Interactions With Avatars

Tatiana Popova, Galina Menshikova and Olga Tikhomandritskaya
Faculty of Psychology, Lomonosov Moscow State University, Russia

We investigated the gender differences of participant's behavior during the interaction with avatars of different ethnic appearance. Forty participants (19 males and 21 females aged 18–23 years) were tested. Virtual scenes were presented using the CAVE virtual reality system. Behavioral characteristics were analyzed including average minimal and maximal interpersonal distances. The results showed the compensation effects in interpersonal distances: shorter – with avatars which appearance represented own subject's ethnic groups and longer – with avatars of other ethnic appearance. It was also found that questionnaire's scores were in good agreement with behavioral characteristics. The gender differences of walking strategy while performing the task were revealed. The obtained results may be useful for developing methods of testing the behavioral patterns during interactions with virtual partners.

Quantifying How Surface Properties Trade Off in Object Selection

Ana Radonjic and David Brainard
Department of Psychology, University of Pennsylvania, PA, USA

Information about object properties (color, material or shape) helps us select objects in goal-directed tasks. We developed a paradigm to investigate how two different visual properties (color and glossiness) trade off in object selection. On each experimental trial, observers view three objects (a target and two tests) and select the test that is most similar to the target. The tests vary, relative to the target, in color (greener or bluer; seven steps) or glossiness (more matte or glossier; seven steps). The data are analyzed via an observer model that recovers the relative weight with which color and glossiness contribute to the judgments as well as the positions of the test stimuli in a perceptual color-glossiness space. To maximize the accuracy of the recovered parameters, we developed an adaptive trial-by-trial stimulus choice procedure using Quest+: On each trial, the test stimuli are chosen to maximize the expected information about the model parameters, given the current data.

Neural and Behavioral Modulations Induced by Transcranial Electrical Stimulations to the Occipital Cortex: Do They Really Modulate Neural Activities?

Yuko Yotsumoto, Zhiwei Fan, Shogo Katsui, Keishi Nomura and Shuhei Shima
Department of Life Sciences, The University of Tokyo, Japan

Transcranial electrical stimulation (tES), a non-invasive brain stimulation technique, has been widely used in the studies of cognitive neuroscience. However, the nature of the actual neural modulations induced by tES remains unclear. We examined behavioral and neural modulations induced by tES applied to the occipital brain area. In the behavioral experiments, transcranial alternating current stimulation at alpha frequencies were applied to the occipital regions during a duration reproduction or a duration discrimination task. We observed minimal to no effects of

tES in the behavioral performance. In the functional magnetic resonance imaging experiment, we measured resting state MRI and blood oxygenation level-dependent (BOLD) activities during a visual task, and compared the effects across different types of tES. The results showed that some tES changed large-scale functional connectivities, but not all tES induced changes in the BOLD activities. We will further discuss the potential bias and problems in the tES studies.

Scene Perception

Magic Circle

Andrea van Doorn[1], Jan Koenderink[2] and Johan Wagemans[2]
[1]Department of Experimental Psychology, Utrecht University, the Netherlands
[2]Brain & Cognition, KU Leuven, Belgium

Full horizon photographs become increasingly common. There are various ways to display such data, but many users prefer what might be called a "post card display," which may be implemented as a Mercator projection of about 2:3 or 3:4 aspect ratio (this implies discarding parts about zenith and nadir). Most viewers interpret such displays as normal views, where everything depicted is actually in front of the camera, whereas in full horizon photographs half of the pictorial content derives from the space behind the camera. We present a striking demonstration of how this easily gives rise to fully erroneous perceptions. We also present a simple model that allows one to predict possible as well as likely interpretations of given scenes.

Semantic Scene Statistics Using a Novel Computational Method

Dylan Rose and Peter Bex
Department of Psychology, Northeastern University, MA, USA

Current salience research aims to extend salience models to include scene context or object-level features. We propose a related method for modeling joint linguistic/visual image content. It measures semantic similarity between objects, as well as between objects and a scene descriptor, using a vector-space language model. These scores are aligned with object masks in-image, allowing inferences on the effect of semantic salience on gaze guidance. We here describe the method and present data on semantic and image saliency gaze guidance for a set of images and visual tasks. Both types of semantic salience map were modestly but significantly correlated with Itti-Koch maps of the same image. Receiver operating characteristic analyses of gaze alignment with both types of semantic maps indicated that they were significantly better predictors of gaze than image salience across tasks. Together, we believe these results support the use of our method, alone or in combination with other salience models, for predicting gaze.

The Gist of a Mammogram Predicts Future Development of Cancer

Karla Evans[1] and Jeremy Wolfe[2]
[1]Department of Psychology, The University of York, UK
[2]Visual Attention Lab, Brigham & Women's Hospital, Harvard Medical School, MA, USA

We are all experts at rapid perception of scene gist. Expert radiologists can detect the gist of medical images; for example, discriminating normal from abnormal mammograms at above chance levels after 500 milliseconds exposure. Under these conditions, localization of any lesion is at chance, suggesting that a global/texture signal underpins the detection of these subtle abnormalities. Gist classification is possible in images from the normal breast contralateral to the breast with overt signs of cancer. Here, we show that three groups of expert observers can also detect the gist signal 3 years before the cancer, itself, appears. This is not due to a few salient cases nor to breast density, a known risk factor. The ability is related to perceptual expertise as quantified by the number of mammographic cases read within a year. Radiologists have access to a global, non-selective signal of abnormality that could serve as a perceptual "risk factor" to be used in early detection of cancer.

Spatial Frequency Tuning for Scene Categorization: The Role of Scene Type and Categorization Level

Sandro Wiesmann[1], Verena Willenbockel[1], Frédéric Gosselin[2] and Melissa L.-H. Vo[1]
[1]Department of Psychology, Scene Grammar Lab, Goethe University Frankfurt, Germany
[2]Département de Psychologie, Université de Montréal, Canada

Fast scene categorization relies on information conveyed by specific spatial frequencies (SFs). We used a high-resolution SF sampling technique to assess the precise SF tuning curves for the rapid basic- and superordinate-level categorization of indoor and natural outdoor scenes. Multiple linear regressions on the random SF filters and transformed response times from correct trials revealed that fast responses in the basic-level categorization task were predicted by two narrow SF bands per scene type,

peaking at 3 and 28 cycles per image (cpi) for indoor scenes and at 2 and 14 cpi for outdoor scenes. Quick superordinate-level categorization (indoor vs. outdoor scenes) relied on one broader SF band ranging from 1 to 14 cpi, indicating that fine-scale information was less relevant for this task. Overall, our results suggest that both low and specific higher SFs contribute to fast scene categorization, although the precise SF tuning curves differ as a function of scene type and categorization level.

Restorative Effects of Nature (Images): The Role of Visual Processing

Claudia Menzel and Gerhard Reese
Department of Social, Environmental and Economic Psychology, University of Koblenz-Landau, Germany

Viewing nature compared to urban scene images improves mood and restoration. We investigated whether differences in image properties between the two scenes contribute to these effects. We used phase-randomized images to test whether these elicit similar effects as original images. Original and phase-randomized images of nature and urban scenes were presented to different groups of participants. Original—but not phase-randomized—nature compared to urban image presentation led to higher restoration, liking, and connectedness to nature. Further, we run association tests with both types of images and several attribute dimensions. Results indicate that original—but not phase-randomized—nature compared to urban images were associated more with positive attributes. Thus, phase-randomized images do not evoke similar associations and effects as original images. Therefore, low-level visual processing seems to play only a minor role in explaining restorative effects of nature.

Measuring Boundary Extension in the Central Area of Images

Jiri Lukavsky[1], Vojtech Klinger[2] and Filip Dechterenko[1]
[1]Institute of Psychology, Czech Academy of Sciences, Czech Republic
[2]Applied Neurosciences and Brain Imaging, National Institute of Mental Health, MD, USA

Is boundary extension (BE) present for central area of photographs? We introduced internal boundaries with cut-out holes or black ink blobs. In Experiment 1, we presented 24 printed photographs with cut-out holes. After 15 seconds, participants received alternative version and were asked to reproduce the shape and size of the hole (BE task) or to identify change (distractor task). We found people drew holes smaller by 12.6% (95% confidence interval [CI] = [−15.0, −10.4], $N = 32$). In Experiment 2, we replaced holes with ink blobs and found similar bias (−8.6%; 95% CI = [−10.9, −6.5], $N = 30$). We ran two computer versions with size adjustment. In Experiment 3, the initial blob size was minimal to mimic the reproduction task and the responses were also smaller (−8.2%; 95% CI = [−11.4, −4.9], $N = 30$). However, the preliminary results of Experiment 4 suggest the bias disappears with random initial size (+0.6%; 95% CI = [−4.5, 5.7], $N = 11$). Remembering smaller holes or blobs is likely caused by the preview of hidden content in reproduction tasks.

Predicting Scene Perception in Patients With Cerebral Blindness

Anna Geuzebroek[1] and Albert V. van den Berg[2]
[1]Donders Centre for Neuroscience, Donders Institute, the Netherlands
[2]Centre of Cognitive Neuroscience, RadboudUMC, the Netherlands

While walking through the world, we are continuously confronted with novel environments. This forces us to keep updating the sequences of actions accordingly. Rapidly perceiving scene- and navigation-related information is therefore an important ability. But what happens when you lose part of your visual field. This is what patients with cerebral blindness resulting from post-chiasmatic lesions encounter. To address this question, we need objective tools that can account for the large variability in patients experience. By testing and comparing several models, such as GIST, HMAX, and CNN, we have been able to predict behavior of healthy controls in conditions of simply masking part of the scene. We find, however, that most patients' responses cannot simply be explained by masking scenes with their individual visual field defects. We believe that this new approach can be used as a tool to start identifying between patients with problems with more global visual information processing.

Does Low- and Mid-Level Visual Information Allow for Conceptual Analysis in an Ultra-Rapid Serial Visual Presentation Task? An Extended Replication

Lynn K. A. Sörensen, Dorina De Jong, Heleen A. Slagter and H. Steven Scholte
Department of Psychology, University of Amsterdam, the Netherlands

Human observers can detect if an image of a conceptual target category (e.g., smiling couple) is present in an image sequence, even when presented for only 13 milliseconds/image. This has led some to conclude that a full conceptual analysis of an image can be performed based on very brief visual exposure facilitated by feedforward processing, without feedback. This interpretation assumes that the distractor images control for low- and mid-level visual features resulting in the need for conceptual analysis of every picture in the sequence. Here, we performed a replication of the original study ($n = 18$). We extended our replication by including a condition ($n = 18$) in which the original images were replaced with generated copies optimized to contain low- and mid-level visual information. This study clarifies whether a simpler explanation, visual analysis of the image stream, can also explain the performance of subjects in rapid serial visual presentations.

Visual Memory for Fragmented Scenes

Filip Dechterenko[1], Katerina Koppova[2] and Jiri Lukavsky[1]
[1]Institute of Psychology, Czech Academy of Sciences, Czech Republic
[2]Faculty of Arts, Charles University, Czech Republic

We are surrounded with tremendous amount of visual information. If we see a picture, do we remember the general shape or individual details? In this study, we created stimuli by merging individual patches from the three different photographs. Original images were divided into 4×4 patches, and stimuli were created by randomly selecting 8, 5, and 3 patches from each image. We showed 240 images to 30 participants. Each image was shown for 3 seconds and after the presentation, small patch was displayed (either from the seen or unseen part). Results showed that accuracy decreases with increasing number of shown patches (generalized linear mixed model: $\chi^2(1) = 15.36$; $p < .001$) from 62% (three patches) to 56% (eight patches). Additionally, false alarm rate increased with number of shown patches, $\chi^2(1) = 75.37$; $p < .001$. These results suggest that we store smaller number of patches individually, while for larger number of patches, we store the overall shape of the image.

The Influence of Top-Down Contextual Predictions on the Processing of Low-Contrast Feedforward Input

Gemma Donnelly, Johanna Bergmann, Matthew Bennett, Lucy Petro and Lars Muckli
Institute of Neuroscience and Psychology, University of Glasgow, UK

When a physical input is weak or ambiguous, the brain uses surrounding contextual information to process this input. Our study shows that subjects' ability to accurately identify low-contrast information is higher when it is surrounded by consistent contextual information than when the surrounding context is inconsistent. Despite differences in identification accuracy between conditions, detecting the presence of this low-contrast input remains at around chance level suggesting the ability to identify this information may stay largely intact in the absence of conscious perception. Increase in contrast parametrically increases both identification and detection accuracy; however, differences in identification accuracy persist at subthreshold contrasts. Our results show that top-down predictions facilitate the processing of consistent, but weak, feedforward information and they interfere with inconsistent bottom-up signals; reinforcing the notion of predictive visual processing.

The Influence of Visual Long Term Memory on Eye Movements During Scene Viewing

Lisa Schwetlick, Hans A. Trukenbrod and Ralf Engbert
Allgemeine und Biologische Psychologie, University of Potsdam, Germany

Visual long-term memory (VLTM) has a high capacity, persists over large time spans, and has been found to influence eye movements during scene viewing. These effects have only been investigated on short time scales, by repeated image presentation within the same session. The present study investigates the transfer of these effects to longer time scales. Participants viewed images over three sessions separated by several days. All images were unfamiliar to participants in the first session. In subsequent sessions, images were (a) unfamiliar, (b) familiar, or (c) semantically and structurally similar to previously seen images. Although subjects showed the expected proficiency in recognizing images, we found no or only weak effects of image familiarity on eye movement measures (e.g., fixation durations, saccade amplitudes, central fixation bias). Our results reveal that scene exploration is primarily driven by the current visual input and only weakly modulated by VLTM from previous days.

Temporal Processing of Scene Gist Between Central and Peripheral Vision With a 180° Visual Field

Clement Beugnet, Sebastien Szaffarczyk and Muriel Boucart
Action-Vision-Learning Team, Laboratoire de Sciences Cognitives et Affectives—SCALab UMR 9193, France

Scene gist recognition—identifying the basic category of a scene—necessitates few dozens of milliseconds in central vision, but peripheral vision is still efficient and even more useful for that purpose. Here, we investigated spatio-temporal processing of scene gist between central and peripheral vision. Using a window/scotoma paradigm, 16 participants had to categorize scenes shown for 33 milliseconds on a 180° panoramic screen. The peripheral part of the scenes was displayed according to a varying stimulus-onset asynchrony from the central part. Central and peripheral information were either congruent or incongruent. Categorization accuracy was impaired by peripheral conflicting information when closer to the central visual field. Facilitation on temporal processing only occurs when peripheral information was displayed after central perceptive processes. Results are in favor of a zoom-out hypothesis of scene gist extraction, which implies a growing attentional focus over space and time during the first fixation.

The Preferred Physical Size of Moving Images Varied With Viewing Distance But Not With Screen Size

Masamitsu Harasawa[1], Yasuhito Sawahata[1], Yamato Miyashita[1], Kazuteru Komine[1] and Satoshi Shioiri[2]
[1]Science and Technology Research Laboratories, Japan Broadcasting Corporation, Japan
[2]Research Institute of Electrical Communication, Tohoku University, Japan

We investigated the effect of viewing distance and screen size on the preferred physical size of the moving images. Participants observed 100 five-second moving images on 8K-resolution screens and reported their size preference in 2AFC (shrink/enlarge) by constant stimuli method. The 50% thresholds as the ratio to the full-screen were defined as the preferred physical size of each movie. There were the three conditions of screen size, 55″, 85″, and 300″ and the two conditions of viewing distance, 75% and 150% of the screen heights. In all conditions, preferred sizes were larger for natural sceneries and long-shots and were smaller for zoomed objects, persons or faces. While the screen size showed no effects, the longer viewing distance conditions showed that 20% larger preferred size than the shorter distance conditions. This distance effect varied with movies along with their averaged preferred size, the movies with the smaller preferred size showed the larger effect.

Density Discrimination in 3D Clutter: Are We Up-Front About It?

Milena Scaccia and Michael Langer
School of Computer Science, McGill University, Canada

We examined how well observers can discriminate the density of surfaces in three-dimensional (3D) clutter such as foliage. Our clutter consisted of squares of constant size that were randomly distributed in a sphere that rotated back and forth about the horizontal axis. The observer's task was to judge whether the front half or back half of the clutter had greater density. Several depth cues were available including occlusions, depth-luminance covariance, and perspective. Two square sizes were compared. We found that, for the larger squares, observers were biased to judge the front half as denser. This is contrary to previous studies of motion and stereo transparency in layers which found a bias for greater density in the back layer. The difference in findings may be due to occlusions which in our study provide a strong ordinal depth cue but which also limit the visibility of the deeper elements in the volume, and more so with the larger squares than smaller squares.

Spatial Vision

Quadratic Mapping Function in Space Perception

Toshio Watanabe
Faculty of Environment and Information Studies, Keio University, Japan

Afin transformation describes the linear mapping between two dimensional spaces. For example, a square is mapped to a parallelogram. In considering the mapping between physical space and visual space, a linear mapping function like afin transformation may not be sufficient. A nonlinear mapping function will be more sufficient to describe the mapping from physical space to visual space because a physical straigth line will be perceived as a curved line. A quadratic mapping function, $u = a11x\text{^}2+a12y\text{^}2$, $v = a21x\text{^}2+a22y\text{^}2$, describes the transformation from a line to a curve. Especially it is effective to describe non-Euclidean property of visual space. Euclidean squares are transformed to non-Eucledian squares, like hyperbolic or elliptic squares. This means the quadratic mapping may make us to find the type of geometry of visual space. Furthermore, in using the quadratic mapping, a square

changes various forms. It may make us to find the beauty of the form.

Lateral Inhibition Linked to Perceptual Filling-In of Sinusoidal Annulus

Yih-Shiuan Lin[1], Chien-Chung Chen[2] and Mark Greenlee[1]
[1]Department of sychology, Universität Regensburg, Germany
[2]Department of Psychology, National Taiwan University, Taiwan

Perceptual filling-in happens when our visual system compensates for lost information in a scotoma with surrounding features. We studied how filling-in affects the perceived orientation of a Gabor target with an adaptation paradigm using three adaptors: one with the same spatial extent of the target, an annulus with no overlap with the target, and a disk the sum of the previous two. For the annulus, observers were asked about the perceived extent of filling-in. On each trial, a flickering adaptor was displayed prior to the target. In a 2AFC adaptive-staircase paradigm, observers judged whether the target was tilted clockwise or counter-clockwise compared to a reference orientation. Threshold elevation was greatest after adapting to the same-sized adaptor, intermediate to the composite adaptor, and smallest to the annulus adaptor. The results suggest that the annulus surround can cancel the effect of the central adaptors. Such lateral inhibition is a candidate mechanism for filling-in.

The Effect of Body Orientation on the Acquisition of Cognitive Mapping

Galina Menshikova and Elena Natura
Department of Psychology, Lomonosov Moscow State University, Russia

The purpose of our work was to study the effect of body orientation on the effectiveness of cognitive map acquisition (CMA). We assumed that a change in body orientation (vertical and horizontal) would worsen CMA formation. Nine virtual mazes were created, differing in configuration complexity. Mazes were presented using Oculus Rift DK2. The experiment included three stages: during the first and third control stages, CMA testing was carried out under vertical body orientation, during the second—horizontal orientation. Fifteen participants were tested. Their task was to remember the maze spatial structure and then to reconstruct it using Sketch mapping method. The analysis showed that the number of errors in the assessment of maze spatial arrangement for the second stage was significantly higher as compared to control stages. The number of errors increased also with increasing configuration complexity of the maze. The study was funded by RFBR project #17-29-02169.

Interpersonal Distance in Field-Theoretical Terms

Robin Welsch, Christoph Freiherr von Castell and Heiko Hecht
Department of Experimental Psychology, Psychologisches Institut Mainz, Germany

Previous studies have found violations of preferred interpersonal distance, for example, someone approaching very closely, to be associated with discomfort. However, the exact function linking discomfort to interpersonal distance has not yet been specified. In this study, we explore the relation between interpersonal distance and discomfort and extend previous findings with regard to intrusions into personal space as well as maintenance of distances outside of personal space. We presented subjects with 15 interpersonal distances ranging from 40 to 250 cm and obtained verbal and manual ratings of discomfort. Compensatory behaviors such as gaze aversion or shift in distance were controlled for. We found discomfort and interpersonal distance to strongly depend on the size of personal space. Whereas discomfort rose rapidly when personal space was entered, the gradient was less steep for distances exceeding the limits of personal space.

Influence of Time in Representing Different Regions of Space

Elena Aggius-Vella, Claudio Campus and Monica Gori
Unit for Visually Impaired People, Istituto Italiano di Tecnologia, Italy

Studies showed the interaction between processing spatial and time domains. However, space is not coded by the brain uniformly. Therefore, it is unclear if the perception of space and time interact similarly in all spaces. In this study, we investigated if time affects similarly perception of the frontal and rear auditory space. Ten subjects performed a spatial bisection task in the frontal and rear space; they had to judge the spatial relation between third sounds. We manipulated time between the sounds, leading to a contrast between spatial and temporal domains. Results show that when time helps in solving the task, performance in the frontal and rear space is similar. Interesting, when time is in contrast with space, performance in the rear space is worse than in the frontal, suggesting that time helps to build a spatial auditory map in the rear space. These results support the role of visual calibration in the spatial task and suggest an important role of hearing in the rear space.

Fine Scale Measurements of the Blind Spot Borders

Annegret Meermeier[1], Markus Lappe[1] and Michele Rucci[2]
[1]Department of Psychology, University of Muenster, Germany
[2]Department of Brain and Cognitive Sciences, University of Rochester, NY, USA

The blind spot is both a nuisance and a necessity for seeing, since it represents the position at which the optic nerve leaves the retina. Although the blind spots presence and position (approximately 15° in the lateral periphery) have been studied, the precise way in which vision transients into blindness is to date unknown. A chief challenge to a precise mapping of this transition is the inevitable wandering of the human fovea even during careful fixation, causing mapping results to be spatially smeared. Using retinal stabilization on a dual purkinje eye tracker (DPI), we mapped the blind spot borders of five subjects' right eye along the horizontal meridian. In one trial, the high-contrast probe (2 × 2 minutes of arc) was presented briefly (14 milliseconds) at randomized positions. Detection rate dropped from 75% to 25% in 10.8′ (3.89) at the nasal blind spot border and increased from 25% to 75% within 17.2′ (8.07) at the temporal border. There was substantial variation between subjects.

Differential Interocular Suppression With Increments and Decrements

Akash Chima, Monika Formankiewicz and Sarah Waugh
Department of Vision and Hearing Sciences, Anglia Ruskin University, UK

Vision is more sensitive to luminance decrements than increments. Suppression for luminance (L), luminance-modulated noise (LM) and contrast-modulated noise (CM) stimuli was investigated for increment versus decrement modulations. Normal observers with monocular neutral density filters made dichoptic perceptual matches of sectors with binocularly viewed adjoining rings, across ±12 lateral visual field. For L stimuli, decrements revealed central suppression ($p < .05$). Suppression of L increments was deeper than for L decrements ($p < .05$), and more evenly spread across the visual field. Suppression to LM stimuli showed smaller polarity differences. Suppression to CM stimuli was central, deeper than for L/LM stimuli ($p < .05$), and did not show polarity differences. L/LM polarity suppression differences may result from ON-OFF pathway asymmetry, and differences in local retinal adaptation.

Features of Gamma Oscillation Evoked by Spatial Summation in Mouse Primary Visual Cortex

Ke Chen, Yi-Lei Zhao, Zhao-Hao Su and Xiao-Hua Liang
Center for Information in Medicine, Key Laboratory of Neuroinformation of Ministry of Education, University of Electronic Science and Technology of China, China

In the mammalian V1, the interaction between the non-classical receptive field and classical receptive field is regarded as a neural basis in visual perception. Gamma oscillation in the primary visual cortex is generally considered related to the synchronous integration mechanism. By conducting the extracellular multi-unit activity and local field potential recording, we examined spatial summation characteristics of neurons in V1 from anesthetized C57BL/6 mice. These neurons are classified into inhibitory and facilitatory cells by multi-unit activity. Our results show similar surround suppression was calculated by multi-unit activity and gamma power (30–60 Hz), which is different from previous results in monkey. Moreover, we observed changes in beta power (20–30 Hz). Our results suggest that facilitatory neurons mainly modulate beta oscillation, while inhibitory neurons modulate both beta and gamma oscillation.

Mesopic Contrast Thresholds at Four Parafoveal Locations

João Lourenço, Stephanie Mroczkowska and Luis Garcia Suarez
School of Health Professions, University of Plymouth, UK

The aim of this study was to measure parafoveal contrast sensitivity where the rod density is maximum under three mesopic levels (10, 1, 0.1 cd/m^2) and create a baseline of healthy subjects for further studies. An achromatic Gabor patch of 0.25 c/° (1 cycle, 4° size) was displayed using a 4AFC paradigm at four cardinal locations (7.5° from centre). Detection and identification thresholds were measured using an interleaved QUEST adaptive staircase. Results show an expected logarithmic unit difference in thresholds between mesopic levels, the 10 cd/m^2 level having the lowest sensitivity. Detection and identification thresholds were similar across the mesopic levels. Inter-subject variability in sensitivity between the four locations was observed at all levels ($n = 5$). The consistent logarithmic difference in sensitivities between the three mesopic levels provides a strong control baseline. The lack of consistency in location sensitivity needs to be consider in further stimuli design.

Two Mechanisms of Discrimination of Spatial Phase

Endel Põder
Institute of Psychology, University of Tartu, Estonia

It is easy to discriminate certain phase relations in spatial patterns but not others. Phase perception has been found different in the fovea versus periphery, and for single patterns versus textures. Different numbers of mechanisms have been proposed to account for the observed regularities. This study attempts to better understand the mechanisms behind discrimination of spatial phase. Gabor patches of sine and cosine phases, and textures composed of these patterns, were used as stimuli. To reveal the role of luminance cues, histogram matching of patterns with different phases was used. Effects of attention were studied using visual search experiments with varied set size (1 to 4). The results indicate that phase discrimination is mediated by two types of mechanisms. The first uses luminance differences and operates pre-attentively, in parallel across the visual field. The second compares relative positions of dark and bright segments and is strictly limited by capacity of attention.

Different Property by the Axis Direction Crossing Diagonally Each Other in Gaze Perceptional Space

Masaki Mori[1] and Toshio Watanabe[2]
[1]Graduate School of Media and Governance, Keio University & Japan Society for the Promotion of Science, Japan
[2]Environment and Information Studies, Keio University, Japan

Most of the previous studies on anisotropy have shown that perceptual space has the different property with the direction of the perpendicular axis in a physical space. This study investigated whether the perceptual space has the different property with the direction of the oblique axis (which is called "diagonaltropy"). A transformation matrix in a mapping function was decomposed to show a diagonaltropy. Our study used the gaze perceptional space (GPS) as data of perceptual space. The results showed that the first axis in the GPS was rotated counterclockwise by 2.3° from the horizontal axis in the physical space. The second axis in the GPS was rotated clockwise by 7.6° from the depth axis in the physical space. The GPS was scaled 1.227 times in the first axis and 0.516 times in the second axis more than the space after the rotation. We found that the GPS has a diagonaltropic property. Furthermore, a diagonaltropy is shown by the mapping function.

Mental Rotation of Simulated Haptic Representations

Ruxandra Tivadar[1], Tom Rouillard[2], Cédrick Chappaz[3], Jean-François Knebel[4], Nora Turoman[1], Fatima Anaflous[5], Jean Roche[5] and Micah Murray[6]
[1]CHUV-Radiology and Clinical Neurosciences, University of Lausanne, Switzerland
[2]Software Engineering, Hap2u, France
[3]Project Management, Hap2u, France
[4]EEG Brain Mapping Core, Centre for Biomedical Imaging, University of Lausanne, Switzerland
[5]Ophtalmologie, Fondation Asile des Aveugles, Switzerland
[6]Department of Radiology and Clinical Neurosciences, CHUV—The Laboratory for Investigative Neurophysiology, Switzerland

It is unknown whether individuals can create and manipulate spatial representations based on simulated haptic sensation. In partnership with Hap2u, we studied a new technology that renders haptic feedback by modulating the friction of a flat screen through ultrasonic vibration of varying amplitude. We reasoned that participants should be able to create mental representations of letters presented in normal and mirror-reversed haptic form and manipulate them in a mental rotation task. Normally sighted, blindfolded participants felt letters at different rotations on a tablet, and indicated their perception of the presented form. We observed a prototypical effect of rotation angle on performance consistent with mental rotation of these haptically rendered objects. Our findings significantly extend research in sensory substitution by indicating that simulation of active haptic sensations can support spatial functions and may thus be a valuable tool in the mitigation of visual impairments.

Surface and Texture

Adaptive Comparison Matrix for Psychological Scaling

Isamu Motoyoshi and Saya Kashiwakura
Department of Life Sciences, The University of Tokyo, Japan

Perception studies often need to quantify subjective intensity along a particular dimension for a large number of stimuli whose perceptual ordering is unknown. Here, we propose an experimental protocol of comparative judgments that can rank and scale subjective stimulus intensity using a small number of trials. On each trial, observer views a list of M stimuli taken from N stimuli, and repeatedly choose the stimulus that elicits maximum subjective response along a given dimension (e.g., the most attractive) until the last stimulus remains. The method sort the stimulus order in the $N \times N$ comparison matrix via logistic

regression and samples the next set of M stimuli whose expected response ratio is close to 0.5. Numerical simulations showed that the method can efficiently estimate psychological scale for hundreds of stimuli. Human experiments also confirmed that the method can quickly estimate magnitude along perceptual dimensions such as contrast, glossiness, and facial expression.

Modulating Luminance and Color Saturation Disambiguates Mirror and Glass

Hideki Tamura[1], Eugen Prokott[2] and Roland Fleming[2]
[1]Department of Computer Science and Engineering, Toyohashi University of Technology, Japan
[2]Department of Experimental Psychology, Justus-Liebig-University Giessen, Germany

Distinguishing mirror from glass is challenging because both materials derive their appearance from their surroundings. A ConvNet trained on over 750,000 mirror and glass renderings correlates quite well with human glass versus mirror judgments. Here, we report that ambiguous images can be made to look like either mirror or glass by modulating specific image features. We found that mirror and glass images have markedly different luminance and color saturation profiles along trajectories from the object's center of mass to its contour. Mirrors tend to have high luminance and saturation, while for glass, luminance gradually increases from center to fringe. We changed these features for stimuli that were judged neither mirror nor glass. The resulting images appeared more mirror-like or glass-like accordingly. These results suggest that the visual system uses such simple cues derived from luminance and color saturation profiles to distinguish mirror from glass.

Estimating Perceived Viscosity of Liquids With Neural Networks

Jan Jaap R. van Assen[1], Shin'ya Nishida[2] and Roland Fleming[1]
[1]Department of Psychology, Justus-Liebig-University Giessen, Germany
[2]NTT Communication Science Laboratories, Japan

Visually estimating the intrinsic properties of liquids is challenging because of their complex, highly mutable nature. Here, we investigated whether relatively simple neural network architectures can predict human errors in estimating viscosity in short animations. We simulated a training set of 100.000 movies depicting liquids in 10 different scenes with 16 different viscosities, which we used to train a range of feedforward neural networks. Observers rated viscosity for a subset of the stimuli. Using Bayesian optimization, we searched for network hyper-parameter values (e.g., kernel size, learning rate) that best predicted the observers' ratings. We find that optimized networks were roughly as good at predicting mean observer performance as individual observers were, and that they mimicked the pattern of errors across stimuli as well. This provides new insights into the image cues humans may exploit to identify liquids and their properties.

Image Cues for Glossiness Perception Obtained From Low Luminance Specular Reflection Components

Hiroaki Kiyokawa, Tomonori Tashiro, Yasuki Yamauchi and Takehiro Nagai
Department of Informatics, Yamagata University, Japan

Kim et al. suggested that low luminance regions of specular components, not only highlights, contribute to glossiness perception, though image cues for such glossiness is still unclear. To clarify cues for glossiness based on low luminance regions, we performed some experiments. First, we measured perceived glossiness on a number of computer-graphics object images with and without highlights (Full and Dark conditions). Second, we measured some image features of stimulus images such as luminance edge amounts and highlight-related features. Finally, we examined relations between the measured features and perceived glossiness with a multiple regression analysis. In the results, the luminance edge amounts most strongly contributed to glossiness among the measured features, especially on objects whose glossiness scores are higher in Dark condition than in Full condition. These results suggest that luminance edges are an effective cue for perceived glossiness in low-luminance regions.

Effect of Glossiness on the Impression Evaluation of Paint Color

Kentaro Inomata[1], Go Fujii[1], Noriko Nagata[1], Ayumi Ohkushi[2] and Toshitaka Koyama[2]
[1]School of Science and Technology, Kwansei Gakuin University, Japan
[2]Nippon Paint Holdings Co., Ltd, Japan

The findings of existing studies on the effect of glossiness on paint color impression evaluation differ considerably. Moreover, these studies have used limited colors or employed fewer controls for color differences. In this study, we examined the effect of texture on subjective impressions using paint of the same color. The stimuli

were 44 plates of glossy and matte paint in 22 colors created by paint-manufacturing experts. Ten participants evaluated the stimuli. Factor analysis revealed a two-factor solution that accounted for 81.57% of the variance, and each factor was interpreted based on area and decoration. The *t* tests of factor scores for each color showed that the effect of the texture was seen in parts with high color saturation, regardless of hue and brightness. This suggests that the influence of texture on impression evaluation may vary based on saturation rather than hue and brightness.

Using Neural Networks to Distinguish Gloss From Matte Textured Materials

Eugen Prokott[1], Hideki Tamura[2] and Roland Fleming[1]
[1]Department of Psychology, Justus-Liebig-Universität Gießen, Germany
[2]Department of Computer Science and Engineering, Toyohashi University of Technology, Japan

The visual computations underlying human gloss perception remain poorly understood. We took a data-driven approach, by training Convolutional Neural Networks (CNNs) on large numbers of images and searching for architectures that correlate with human judgments. We created 75,000 scenes with varying objects, lighting and viewpoints, and rendered high gloss (mirror-like) and low gloss (near-matte) versions of each scene. Texture patterns on the low gloss surfaces ensured that contrast and saturation alone could not distinguish the two classes. After asking observers to classify a large number of images into high versus low gloss, we selected a test set ranging from consistently correctly to consistently incorrectly judged images. We also used Generative Adversarial Networks to create additional ambiguous test images. Using Bayesian hyper-parameter search we identified CNN architectures that, when trained on the remaining renderings, correlated highest with humans on the benchmark test set.

Robustness of the Texture Filling-Out Induced by Masking of the Stimulus Contour

Shuichiro Taya
Hiyoshi Psychology Laboratory, Keio University, Japan

When a textured circle is presented immediately after a high-contrast line which masks the circle's contour, the texture subjectively spreads to the non-textured peripheral visual field, and fills the entire field of view. Three experiments were conducted on this 'mask induced filling-out (MIF)', using the size of the stimulus, positions of the textured circle and the mask, and the eyes for stimulus presentation (dichoptic/monoptic) as independent variables. The results showed that the participants 'saw' the illusory texture filling the entire display (55° in diagonal), even if the texture covered only a small (5.4° diameter) area of the display. The same results were obtained even if there was a gap between the contour of the textured circle and the mask, and if the stimuli were presented dichoptically. This robust nature of the MIF is not concordant with the previously reported filling phenomena (e.g., contour adaptation), suggesting differences in the underlying mechanisms.

Aspects of Material Softness in Active Touch

Dicle Dovencioglu[1], Katja Doerschner[2] and Knut Drewing[1]
[1]Department of Psychology, Justus Liebig University Giessen, Germany
[2]Justus Liebig University Giessen & Bilkent University, Germany

We investigated haptic explorations used to perceive different aspects of material softness. We analyzed videos in which people haptically explored and judged 50 materials that differed in deformability, surface texture, granularity and viscosity, with two aims: (a) to mark important anatomical landmarks of the hand involved in exploration and (b) to identify exploratory procedures relating to different aspects of perceived softness. Results showed that participants used mostly their fingertips when exploring granular materials, for example, sand, whereas almost all the landmarks were used to touch textile materials. We identified a new set of eight exploratory procedures that relate to various dimensions of perceived softness: pressure, rub, stroke, rotate, stir, pull, run through, and tap. People regularly rub textile materials with a soft surface, for example, velvet or fur, press deformable materials, for example, sponge, and run granular materials through their fingers, for example, sugar.

Eye Movements to Orientation Defined Texture: The Effect of Pattern Configuration

Shumetha Sidhu and David Keeble
School of Psychology, University of Nottingham, Malaysia Campus, UK

We constructed texture patterns with lines that differed in orientation between figure and ground. The orientation change between figure and ground had three possible configurations: maximum orientation contrast at edge of the

figure (Cornsweet), centre of the figure (Blur), and at both edge and centre of the figure (Block). Participants performed a matched saliency task, in which they were presented with two textures on either side of fixation, and had to make a saccade to the texture that had the figure that was most noticeable within the texture. The Block profile was found to be most salient, because a higher mean orientation contrast was needed by the Blur (67°) and Cornsweet (40°) profile to match the saliency of the Block profile at 30° orientation contrast. Our results imply that maximum orientation difference at the edge and centre of a figure produces the highest levels of saliency for driving eye movements.

Estimates of Surface Friction Are Primarily Driven by Linear Motion

Robert Ennis[1] and Katja Doerschner[2]
[1]Department of Psychology, Justus Liebig University Giessen, Germany
[2]Justus Liebig University Giessen & Bilkent University, Germany

Visually estimating the smoothness or roughness of objects is important for many activities such as picking up objects, supporting ourselves on objects, or letting them slide down other surfaces. The friction that an object might experience could be visually determined from optical material properties, body mechanics (soft vs. rigid), or how they move under the influence of gravity. Here, we presented observers with computer rendered videos of cuboids dropping onto and sliding down an inclined plane. Three optical material types (matte, transparent, glossy) and two body types (soft/rigid) were tested. The simulated coefficient of friction was varied over six steps. In a 2IFC experiment, observers choose the "smoother" cuboid for each pair of friction, making comparisons within optical materials and within body types. Results suggest that observers' judgements are independent of body and optical material type, implying that friction judgements may primarily be based on linear motion.

Temporal Processing

How Do "Duration Selective" Brain Regions Communicate?

Foteini Protopapa[1], Masamichi Hayashi[2] and Domenica Bueti[1]
[1]Cognitive Neuroscience, SISSA, Italy
[2]Graduate School of Frontier Biosciences, Osaka University, Japan

To answer the question of "where" in the human brain the encoding of different durations takes place, we ran an functional magnetic resonance imaging experiment at ultra-high field (7T) in which we asked participants to discriminate visual stimuli of different durations (from 0.2 to 1 second). The results identified the existence, in the Supplementary Motor Area (SMA), and in the medial and lateral Inferior Parietal Lobule (IPL) of the left hemisphere, of neuronal units maximally responsive to the different durations. To investigate the functional relationship between IPL and SMA , we employed dynamical causal modeling and assessed the effective connectivity of the 3-node network. Bayesian model selection between different possible models lead to the conclusion that temporal information is first received by both lateral and medial IPL and then sent to SMA via feedforward connections. Parametric empirical Bayes analysis revealed that the neural mechanisms that underlie time perception support bottom-up connections.

Spatiotemporal Feature Integration Within Discrete Time Windows Provides Evidence for Discrete Perception

Leila Drissi-Daoudi, Adrien Doerig and Michael H. Herzog
Laboratory of Psychophysics, Brain Mind Institute, Ecole Polytechnique Fédérale de Lausanne, Switzerland

Intuitively, consciousness seems to be a continuous stream of percepts. Here, contrary to intuition, we show evidence for discrete consciousness, occurring only at certain moments of time. We presented a Vernier followed by a sequence of flanking lines on either side, leading to the percept of two diverging motion streams. The Vernier offset is visible at the flanking lines even though the Vernier itself is invisible due to metaconstrast masking. If an additional offset is introduced to one of the flanking lines, the two offsets integrate. Here, we show that this feature integration is mandatory and lasts up to 450 milliseconds. Surprisingly, when the offset is presented at 330 milliseconds stimulus-onset asynchrony (SOA) it integrates with the central offset but not with a third offset presented at 490 milliseconds SOA, even though the latter two are much closer in space and time. This result suggests that only features that are presented in the same time window integrate, supporting the concept of discrete consciousness.

Low Frequency Repetitive Transcranial Magnetic Stimulation to Right Parietal Cortex Disrupts Perception of Briefly Presented Stimuli

Christina Howard, Hayley Boulton, Stacey A. Bedwell, Charlotte A. Boatman, Kate L. Roberts and Suvobrata Mitra
Department of Psychology, Nottingham Trent University, UK

Right parietal cortex has recently been linked to the temporal resolution of attention. We therefore sought to investigate whether disruption to right parietal cortex would affect attention to visual stimuli at fine timescales. Participants performed a visual discrimination task with briefly presented stimuli immediately following either no transcranial magnetic stimulation or after 10 minutes of repetitive transcranial magnetic stimulation at 1 Hz to right or central parietal cortex. Participants reported the spatial frequency of a masked Gabor patch presented for either 60, 120, or 240 milliseconds. We calculated error magnitudes by comparing accuracy to a guessing model. We then compared error magnitudes to baseline blocks with no stimulation, producing a measure of baselined performance. Baselined performance was poorer after right parietal than central parietal stimulation, suggesting that right parietal cortex is involved in attention at fine timescales, particularly in situations where rapid accumulation of visual evidence is needed.

Endogeneous Attention Enhances the Temporal Resolution of the Visual Processing at Different Stages

Makoto Ichikawa
Department of Psychology, Chiba University, Japan

We aimed to understand how the endogenous attention affect the teporal resolution of the visual processing. We measured different indexes concerning with temporal resolution of the visual processing with/without endogenous attention by the use of the method of constant stimuli; the flicker detection threshold for a target (Experiment 1), or the inspection time, which is related to the peformance IQ, for a target composedd of two vertical lines with different length (Experiment 2), which were presented at left or right of a fixation point. In each trial, an arrow was presented to directs the participant's endogenous attention to left or right of the fixation point. Participant judged the location of the target, and then reported whether they perceive flicker for the target (Experiment 1), or which of the vertical lines is shorter than the other (Experiment 2). Results suggest that the endogenous attention improves the temporal resolution of the visual processing at different stages.

Population Receptive Field Mapping Reveals Topographical Organisation of Durations

Shrikanth Kulashekhar, Foteini Protopapa and Domenica Bueti
Cognitive Neuroscience, Scuola Internazionale Superiore di Studi Avanzati, Italy

Neuronal receptive fields are a form of tuning functions that reflect aspects of the stimulus space, such as stimulus position in the visual retinotopic maps. In population receptive field (pRF) mapping instead of measuring single neurons, the combined activity of a large number of neurons is acquired through an indirect, metabolic measure of neuronal activity. The aim of this study was to use pRF mapping to test whether stimulus durations have a topographic organisation and the brain areas that support such a representation. We acquired ultra-high-field functional magnetic resonance imaging (7T) data from 10 subjects while they discriminated between pairs of visual stimuli of different durations ranging between 0.2 and 3 seconds. The pRF maps reveal a clear topographical organization of stimulus durations in the supplementary motor area along the rostro-caudal direction, increasing from short to long durations. The results suggest that neuronal tuning mechanism could support the representation of sub-/supra-second durations.

When a Visual Event Is Perceived Depends on How We Attend to Its Temporal Context

Ljubica Jovanovic and Pascal Mamassian
Laboratoire des Systèmes Perceptifs, Département d'études cognitives, École normale supérieure, PSL Research University, CNRS, France

When we perceive an event, is it affected by other events in its temporal proximity? Participants first learn a mapping between time and space by watching the hand of a clock doing a full revolution in a fixed duration. Then, the hand is removed, a disc is flashed within the interval duration, and participants indicate where the hand would have been at the time of the flash. In the experiment, two discs are presented, a target and a distractor, with variable time between them. The target is either known beforehand, or revealed at the end of the trial, from its colour or its temporal order. We find that when a target is perceived depends both on when distractors are presented, and how the target is designated. If participants attend to both discs, the target is attracted to the distractor. A target cued in advance by colour is also attracted by the distractor but only when the distractor appears first. Finally, attending to temporal order biased estimates away from distractors.

The Retinotopic Representation of Time in Visual Cortex

Gianfranco Fortunato[1], Tatiana Kénel-Pierre[2], Micah Murray[2] and Domenica Bueti[1]
[1]Cognitive Neuroscience, SISSA, Italy
[2]Laboratory for Investigative Neurophysiology, Department of Clinical Neurosciences, University Hospital of Lausanne, Switzerland

Performing a timed movement requires for the brain the integration of both temporal and spatial information. How and where the human brain links these two types of information remains unclear. Previous studies have shown that V1 and V5/MT are both involved in the encoding of temporal information of visual stimuli. Here, we tested the hypothesis that these areas encode time in different spatial coordinates. In two distinct experiments where we asked participants to discriminate the duration of visual intervals presented at varying combinations of retinotopic and head-centred positions, we interfered with the activity of the right dorsal V1 and the right V5/MT by means of paired-pulse transcranial magnetic stimulation. The results showed that both V1 and V5/MT encode visual temporal information in retinotopic spatial frames, but the representation of time is quadrant-specific for V1 and hemifield-specific for V5/MT.

Contrast Gain Control in Glaucoma at Photopic and Mesopic Light Levels

Catarina A. R. João, Lorenzo Scanferla and Nomdo M. Jansonius
Department of Ophthalmology, University Medical Center Groningen, the Netherlands

Light adaptation is crucial for visual functioning. In glaucoma, complaints related to dysfunctional adaptation were reported, however, not entirely shown psychophysically. We aimed to determine the influence of glaucoma on adaptation to rapidly changing background luminances (contrast gain control). We measured contrast sensitivity in 25 glaucoma patients and 25 age matched controls. Stimuli were presented on a temporally modulated background. In addition, temporal modulation sensitivity was assessed by showing flickering targets on a static background. In all 56 comparisons (2 eccentricities $\times$ 7 frequencies $\times$ 2 polarities $\times$ 2 luminances), contrast sensitivity was lower for cases than controls, as was the case for temporal modulation sensitivity. The frequency dependencies of contrast gain control and temporal modulation sensitivity were similar for both groups, at both eccentricities and luminances, suggesting a common underlying mechanism.

Time-Based Expectancy for Tasks or for Visual Task Cues?

Irina Monno, Stefanie Aufschneiter, Sonja Ehret, Andrea Kiesel and Roland Tomaschke
Allgemeine Psychologie Cognition, Action, and Sustainability, Albert-Ludwigs-Universität Freiburg, Germany

Previous research has shown that in task switching participants responded faster to tasks validly predicted by a pre-target time interval that to tasks invalidly predicted. But it is still unclear whether this expectation reflects the time-based predictability of the current task set or of the current visual cue. In the present study, we used two pre-target intervals (short and long) which each were combined more or less frequent with one of two arithmetic tasks. Each task was signaled by two different target colors. One of these colors was assigned with 90% validity to one of the two intervals (predicted color), whereas the other color was 50% probable after both intervals (unpredicted color). Performance only improved when color and task were predictable by time (predicted color), not when task alone was predictable (unpredicted color), suggesting a perceptual explanation for the time-based expectancy effect for tasks.

Viewing Emotional Facial Expressions Enhances Temporal Resolution of the Visual Processing

Misa Kobayashi[1] and Makoto Ichikawa[2]
[1]Graduate School of Humanities and Public Affairs, Chiba University, Japan
[2]Faculty of Humanities, Chiba University, Japan

Our previous study showed that the fearful photos would increase temporal resolution of the visual processing. Since we used color photos of everyday objects and scenes to evoke emotion, the image characteristics of photos could differ among conditions. In the present study, to control the image characteristics, we used photos of facial expressions (anger, fear, joy, and neutral) with upright and inverted possessions. As an index of temporal resolution of the visual processing, we measured the threshold duration to notice a brief presentation of monochrome photo in viewing a chromatic photo by using the methods of constant stimuli. We found that the threshold for anger, fear, and joy reduced in viewing upright photos, but not in viewing inverted photos, although the image characteristics were exactly the same between upright and inverted photos. These results suggest that the emotion evoked by viewing facial expressions may increase the temporal resolution of the visual processing.

Sensorimotor Synchronization and Temporal Order Judgements Reveal Saccadic Temporal Recalibration

Dunia Giomo, Brent Parsons and Domenica Bueti
Cognitive Neuroscience, SISSA, Italy

Previous research has demonstrated that adapting saccades to spatially manipulated targets leads to distortions both in subsequent oculomotor commands and in perceptual judgements. Recent findings have shown that manipulations in the temporal domain can also prompt distortions, specifically in saccade velocity and in the perception of sensory targets' temporal features. The current study examined the temporal relationship between saccades and sensory events, by asking whether adapting eye movements to artificially delayed or asynchronous sensory feedback leads to temporal recalibration effects. In two experiments, a sensorimotor synchronization and a temporal order judgement task, we found evidence of recalibration in terms of shifts in saccade synchronization performance and in a perceived reversal of temporal order. This study offers novel insights into the mechanisms underlying perceptual stability and links saccades to the more general phenomenon of motor-sensory recalibration.

tDCS Over Dorsolateral Prefrontal Cortex Modulates Time Perception of Emotional Pictures

Leonardo Gomes Bernardino[1], Evandro Ribeiro Gonçalves Neto[1], Felipe Santos de Oliveira[2] and Rui de Moraes Jr[3]
[1]Instituto de Psicologia, Universidade Federal de Uberlandia, Italy
[2]Instituto de Psicologia, Universidade Católica de Petrópolis, Italy
[3]Instituto de Psicologia, Universidade de Brasília, Italy

Time perception plays a major role in cognitive and motor tasks. The dorsolateral prefrontal cortex (DLPFC) is related to time perception, besides emotional regulation. Thus, we modulated the DLPFC using a transcranial direct current stimulation (tDCS) approach. Participants received 20-minute anodal, sham and cathodal tDCS over left or right DLPFC in three sessions. Then, they performed a long-short presentation categorization of emotional pictures (neutral, positive-high/low arousal, and negative-high/low arousal) as more similar to a short (300 milliseconds) or to a long (600 milliseconds) standard duration. Results revealed time overestimation for positive and negative high arousal stimuli in left and right DLPFC stimulation, respectively. Our results supports previous studies showing that emotional valence and arousal level modulate time perception, probably by changing internal clock system. In addition, such findings provide evidence towards the valence hypothesis of emotion processing.

Changes in Brain Oscillation Frequency Subserve Temporal Processing at Attended Visual Locations

Poppy Sharp, Clayton Hickey and David Melcher
Center for Mind/Brain Sciences, Università di Trento, Italy

Perception requires two opponent processes: Rapid sequential stimuli must often be integrated to form unitary percepts but at other times be segregated or parsed into separate events. Using magnetoencephalography, we characterize the changes in ongoing oscillatory brain activity associated with spatial attention to temporal integration and segregation. We did so by cueing participants to the spatial location where a target would likely occur and requiring them, blockwise, to either integrate or segregate temporal events that occurred at that location. Behavioural results and evoked fields revealed strong spatial cueing effects for both integration and segregation. Neuroimaging results indicated shifts in peak alpha frequency for integration as compared to segregation, as well as different patterns in the unfolding brain signal with respect to cueing conditions. Together, these results provide evidence of strategic shifts in oscillatory frequency in line with task demands.

Bias in Temporal Perception During Aerobic Exercises

Alessia Tonelli and Monica Gori
U-VIP, Istituto Italiano di Tecnologia, Italy

It is known that dynamic visual stimuli modify perceived time. What about changes in body awareness? In this work, we analyze whether time perception, in a duration reproduction task, can be modify by physical activity and the temporal frequency of the presentation of the stimulus. We tested five durations of the stimulus (200, 400, 800, 1,600, and 3,200 milliseconds) that were presented at two temporal frequency: 0 Hz and 2 Hz. Each participant performed the task in a rest condition—he/she was sitting on a chair—and in a "physical" condition—he/she was doing aerobic exercise during the task. Moreover, we recorded the heart rate in each condition. In the "physical" condition, we found an additional modification of the bias in the perceived duration, already known in the literature. During physical activity, participants tend to reduce the dilatation of perceived time comparing to the rest condition, but just for the shorter durations.

Neural Entrainment Tracks the Temporal Structure of Visual Rhythms

Ruichen Hu, Xue Zhang, Yi Jiang and Ying Wang
Institute of Psychology, Chinese Academy of Sciences, China

When chatting with a friend or dancing with our favorite piece of music, neural oscillations are entrained to the rhythm of language or music at multiple temporal scales. Here, we demonstrated analogous hierarchical entrainment effect in the visual modality. Chinese characters or shapes were presented at 4 Hz in random order or forming 1 Hz temporal structure comprising four-character Chinese idioms or shape quadruplets. The regular structures enhanced electroencephalogram power at 1 Hz with distinct topographic distributions, and the entrainment strength predicted the perception of semantic or sensory regularities in the streams. Meanwhile, a 4 Hz entrainment effect spread across the scalp in response to the rhythmic presentation regardless of stimulus type and information regularity. These findings suggest that multiplexed temporal coding through neural entrainment tracks the temporal structure of visual rhythms, which may underlie the encoding and integration of rhythmic information in visual perception.

Beyond Hazard Rate: Response Time Reflects Proactive Preparation for Future Events

Muzhi Wang and Hang Zhang
School of Psychological and Cognitive Sciences, Peking University, China

We investigated a simple response task where subjects made speeded responses to a color change on the screen. The response time (RT) of such task has been found to be inversely proportional to the hazard rate at the target onset, given that the delay of the target (SOA) is uncertain. Here, we provided empirical evidence that RT is determined not merely by the instantaneous hazard rate. In our experiment (six subjects), different blocks differed in the probability distribution for three different SOAs. We compared RTs between conditions that had the same SOA and hazard rate, where we found significant and large differences in mean RTs (e.g., 384 vs. 330 milliseconds, 352 vs. 321 milliseconds). In particular, a higher probability at the shortest SOA reduced the RTs at the intermediate SOA, implying an accumulation effect during the waiting period. These patterns suggest that RTs are more likely to be determined by a proactive preparation process for the future event.

The Encoding of Time in Visual Cortices

Andrea Solmi and Domenica Bueti
Cognitive Neuroscience, Scuola Internazionale Superiore di Studi Avanzati, Italy

A very controversial issue in the field of temporal cognition concerns the role of visual cortices in time computations. A recent transcranial magnetic stimulation (TMS) study has shown that primary visual cortex and extrastriate area V5/MT are necessary to the temporal encoding of visual stimuli. Here, we test the hypothesis that duration encoding occurs through an "accumulation of information" processes and that the timings of the TMS interference on V1 and V5/MT strongly depend on the relationship between TMS pulse and stimulus offset. To test this hypothesis, we stimulated V1 and V5/MT at different timings from stimulus offset (30%, 60%, and 90% of the total stimulus's duration) while we asked participants to discriminate the duration of visual stimuli. The results fit the original hypothesis and help to clarify the functional properties of V1 and V5/MT in time encoding.

Multisensory Duration Reproduction in the Supra-Second Range

Didem Alashan, Resit Canbeyli and Inci Ayhan
Department of Cognitive Science & Psychology, Bogazici University, Turkey

Internal clock model assumes that different sensory modalities use the same mechanism to judge temporal intervals. Here, in blocked trials, we presented participants with an auditory and a visual noise stimuli in five conditions—pure visual, pure audio, audio-visual simultaneous, audio-visual sequential and visual-audio sequential, for seven durations, equally spaced on a logarithmic scale between 2 and 10 seconds and asked to reproduce their perceived durations. Results showed that subjective durations of sequentially presented bimodal stimuli are relatively shorter than those of unimodal or simultaneously presented bimodal stimuli. We also demonstrated that this temporal compression effect cannot be explained by the changes in perceived onsets-offsets of stimuli of different types, implying a genuine duration effect, which we suggest, is caused by an unpredictability introduced by a shift in rather different modality-specific timing mechanisms in the supra-second range.

Visual Search

Attention and Search Tasks in Children With Dyslexia

Khatuna Parkosadze, Tamar Tatishvili, Nino Lomidze and Marina Kunchulia
Institute of Cognitive Neurosciences, Agricultural University of Georgia, Georgia

Dyslexia is neurological in origin but underlying mechanisms are not fully understood and are debated for a long time. Most controversies are concerning the involvement of visual processing. We investigated visual attention and visual working memory in children with dyslexia and their age and IQ match typically developed children using two different search tasks (serial and conjunction search) and visual *n*-back test. No significant differences were found between accuracy of performances of search tasks or memory task. However, reaction times for conjunction task were significantly increased in dyslexic children. No correlation was found between performances of either search tasks or visual memory task. Our results showed no deficits in visual working memory, intact top-down but delayed bottom-up search mechanisms in dyslexic children. We conclude that magnocellular deficits mostly related to dyslexia is not only reason accounting for reading difficulties in dyslexia.

Individual Differences in Exploring 3D Virtual Space

Sören Eckhard[1], Aman Mathur[2], Rupak Majumdar[2] and Tandra Ghose[1]
[1]Department of Psychology, University of Kaiserslautern, Germany
[2]Department of Computer Science, Max Planck Institute for Software Systems, Germany

We study whether it is possible to cluster individual strategies for exploring three-dimensional virtual space into distinct patterns. Participants performed a classic feature search task in VR. The target (red or blue cube) was presented in one of 32 regions centered at the participant's eye level, blocked with 45° increments in radial angle and elevation. The target was embedded in 95, 479, 767, or 1,023 distractors (green cubes/green spheres), equally distributed among the 32 regions. In 33% of trials, both red and blue cubes were present in competing regions—left versus right or diagonally opposite (left-up vs. right-down and vice versa). The task was to find the odd element as quickly as possible and identify its color. Data from 15 participants show that for an individual there is a strong preference for either left or right and up versus down preference. We hypothesize that the preference is driven by ocular dominance and natural posture (walking with head held up/down) of an individual.

All Beginnings Are Difficult: Repeated Search Through Virtual Reality Environments

Dario Stänicke, Dejan Draschkow and Melissa L.-H. Vo
Department of Psychology, Scene Grammar Lab, Goethe Universität Frankfurt, Germany

Understanding how repeated exposure to an increasingly familiar environment guides exploration behavior is crucial for understanding the role of episodic memory in visual search. This question has been investigated predominantly in studies using two-dimensional (2D) stimuli on a computer screen. In our study, participants searched through 3D virtual environments that were either arranged syntactically consistent (e.g., soap on a sink) or inconsistent (e.g., soap on a mirror). Replicating previous work, we show that the usage of episodic memory was stronger within inconsistent environments compared to consistent ones. Critically, we find the strongest improvement in search times directly after the first trial in both experiments. This effect has remained unreported in previous studies, as it is easily masked by averaging. Our results indicate that while a first glimpse of a 3D scene initially takes time, it then guides search even more efficiently than subsequently repeated exposure to the scene.

Color and Orientation Precueing Exert Asymmetrical Effects on Color and Orientation Conjunction Search

Aave Hannus[1], Harold Bekkering[2] and Frans W. Cornelissen[3]
[1]Institute of Sport Sciences and Physiotherapy, University of Tartu, Estonia
[2]Donders Institute for Brain, Cognition and Behaviour, Radboud University Nijmegen, the Netherlands
[3]Laboratory for Experimental Ophthalmology, University of Groningen, University Medical Center Groningen, the Netherlands

Classic visual search theories assume that features are first processed independently and bound together at a later stage. However, neurophysiological evidence suggests the existence of conjunctively tuned visual mechanisms. In two eye-tracking experiments, participants searched for bars combining color and orientation and responded by making a saccade to the perceived target. We determined to what extent precueing with chromatic or orientation information affects subsequent feature discrimination. We find that precueing with achromatic orientation information improved orientation discrimination while simultaneously reducing color discrimination. In contrast,

precueing with chromatic information with irrelevant orientation improved color discrimination without reducing orientation discrimination. These asymmetric effects support the involvement of conjunctively tuned mechanisms in visual search and suggest competition between achromatic and chromatic orientation sensitive mechanisms.

Relevance Affects Repeated Visual Search

Sebastian A. Bauch[1], Christof Körner[1], Iain Gilchrist[2] and Margit Höfler[1]
[1]Institute of Psychology, University of Graz, Austria
[2]School of Experimental Psychology, University of Bristol, UK

When we search the environment repeatedly, not all items might be equally relevant in each search. We investigated in two experiments if and to what extent two consecutive searches in the same display are affected if a relevant target feature is known or unknown at the beginning of a search. Participants searched a display consisting of pink and blue letters twice. Before each search, they knew in advance that the target color in Search 1 could be pink or blue, whereas in Search 2, the target color was always of a fixed color. We found that participants selectively inspected more relevant than irrelevant items in Search 2 compared to Search 1. Furthermore, saccade amplitudes as well as saccadic latencies differed with regard to item relevance in Search 2. This suggests that knowledge of a prospective target feature leads to different search strategies across searches and is applied flexibly in order to make a visual search more efficient.

Probability and Task Relevance Modulate Fixation-Related Potentials in Visual Search With Eye Movements

Hannah Hiebel[1], Anja Ischebeck[1], Clemens Brunner[1], Andrey Nikolaev[2], Margit Höfler[1] and Christof Körner[1]
[1]Institute of Psychology, University of Graz, Austria
[2]Laboratory for Perceptual Dynamics, KU Leuven, Belgium

The detection of a target in visual search has been shown to elicit a P300 in the fixation-related potential (FRP). We investigated the dependence of this P300 on target probability. Electroencephalogram and eye movements were co-registered while participants performed a visual search for targets (one vs. two) among distractors. Set size varied between 10, 22, and 30 items. FRPs for first target fixations revealed a centro-parietal P300 with larger amplitudes for set sizes 22 and 30 than for set size 10. With increasing set size, more distractor fixations preceded the target detection (higher fixation rank), resulting in a lower target probability and, in turn, a larger P300. To evaluate if the effect depends on task relevance, we analyzed FRPs for distractors (fixation rank-matched to targets). Neither did distractors evoke a P300 nor did the amplitude increase with set size. This suggests that the probability of the task-relevant targets but not distractors modulates the P300 in serial search.

Searching Beats Memorizing in Creating Memory Representations for Objects in Realistic Virtual Environments

Jason Helbing, Dejan Draschkow and Melissa L.-H. Vo
Department of Psychology, Goethe University Frankfurt, Germany

How does memory for searched objects compare to explicit memorization? Previous research using two-dimensional (2D) images of real-world environments found free-recall memory performance for targets of visual search to be better than for intentionally memorized objects. The aim of our study was to replicate this finding using a 3D virtual reality paradigm. Participants searched for objects in some scenes and actively memorized visually cued objects in others. An old-new recognition task was used to test identity memory while an immersive rearrangement task tested for location memory. Replicating findings from 2D images, we found that participants were better at identifying objects that were targets of visual search as compared to those we cued for active memorization. This indicates that searching for objects in 3D scene environments creates strong memory representations of these targets; even stronger than intentionally formed representations.

A Simple Model for Short-Term Memory Effects in Repeated Visual Search

Christof Körner[1], Margit Höfler[1] and Iain Gilchrist[2]
[1]Institute of Psychology, University of Graz, Austria
[2]School of Psychology, University of Bristol, UK

When the same display is searched consecutively twice for different targets, the second target is found faster if it was recently fixated in the previous search. This search benefit can be explained by a limited short-term memory buffer that operates according to a first-in first-out principle: Each newly inspected item enters the buffer while the least recent one exits it. Search can thus be guided to items in the buffer when they become a target. Simulations show that this model reproduces the known search benefit for the second target but predicts no further benefit if a search is performed 3 times. We report an

experiment, where we recorded eye movements from participants who performed three consecutive searches. We found the expected search benefit and this benefit did not accumulate across searches, as predicted by our model simulations. This suggests that search with (at least) two repetitions is supported by a limited-capacity short-term memory store.

Human Fixations on Line Drawings of Natural Scenes

Kaifu Yang, Wenwen Jiang and Yongjie Li
School of Life Science and Technology, University of Electronic Science and Technology of China, China

Visual search is an important strategy of human visual system for the fast scene perception and the guided search theory suggests that the layout of scenes plays a crucial role for guiding object search. In this work, we executed psychophysical experiments to observe the human fixations on line drawings of scenes with the eye-tracker system. We collected the human fixations from 498 natural images and the corresponding 996 human-marked boundary maps (two boundary maps per image) with a free-viewing manner. The experimental results show that with the absence of some basic features like color and luminance, subjects still pay more attention to the closed regions of line drawings that are usually related to the dominant objects in the images. Moreover, the distribution of fixations on line drawings has high correlation with that on natural images. These results support that some Gestalt features and the scene layout are the important guiding cues for fast visual object search.

One Item in Visual Working Memory Is an Attentional Template, But Two Are Not: A Successful Replication of Van Moorselaar et al. (2014)

Marcela Frătescu, Dirk Van Moorselaar and Sebastiaan Mathôt
Department of Experimental Psychology, University of Groningen, the Netherlands

Previous studies have shown that items resembling the content of visual working memory (VWM) capture attention. But theories disagree on how many items bias attention. Traditional theories hold that all VWM items bias attention. In contrast, the multiple-state account posits a distinction between template and accessory items, such that only a single template item biases attention. Van Moorselaar et al. (2014) tested this by manipulating the number of items held in VWM. With one item in VWM, they found that a distractor in a visual-search task captured attention more when it matched the content of VWM. Crucially, this effect disappeared with more than one item in VWM. However, other studies produced mixed results, not all in line with the multiple-state account. Therefore, it was important to replicate this result with a large sample. In an adversarial collaboration with the original author, we successfully replicated Van Moorselaar et al.'s results.

Multiplicity of Attention Guidance by Long-Term Memory of Visual Search Arrays: Insights From Event-Related EEG Lateralizations

Artyom Zinchenko, Markus Conci, Thomas Töllner, Hermann Müller and Thomas Geyer
Department of General and Experimental Psychology, LMU, Munich, Germany

If a target item is repeatedly encountered in an invariant arrangement of distractor elements, observers can learn these configurations and use them to expedite search—an effect termed 'contextual cueing'. We examined electro-encephalogram (EEG) correlates of context learning and subsequent adaptation, when target is relocated within an invariant context, requiring observers to adapt previous memory representations. During initial learning, participants showed facilitated search for repeated displays and enhanced activity in the N1pc, posterior contralateral negativity (PCN), and contralateral delay activity (CDA) event-related potential components, indexing early attentional selection (N1pc, PCN) and perceptual discrimination (CDA). However, after target relocation participants showed no benefits of repeated configurations and either a reversal (N1pc) or reduced activity (PCN, CDA) in all three ERP components. This implies that the hindered adaptation effects reflect persistence in matching a given repeated context with the initially learned target location during early visual processing.

Proactive Control Mechanisms for Distractor Expectation in Visual Search

Marco Petilli[1], Francesco Marini[2] and Roberta Daini[1]
[1]Department of Psychology, University of Milan-Bicocca, Italy
[2]Department of Psychology, University of Nevada, Reno

Literature has long investigated the role of top-down processes in visual search. However, whether proactive control processes are involved in single feature search (pop-

out phenomenon) has not been clearly established. We combined visual search and Distraction Context Manipulation paradigm, a method for studying proactive processes of distraction filtering. Accordingly, blocks of visual search trials were of three types: Pure (100% distractor-absent trials), Mixed Feature, and Mixed Conjunction (33% distractor-absent and 66% distractor-present trials each) block. The comparison of distractor-absent trials of Mixed versus Pure blocks helped detecting proactive control processes: Increases of detection sensitivity and slowing-down of response times (RTs) were observed when distractors were expected, yet not presented. Thus, we concluded that distractor expectation recruits proactive control processes that improve detection sensitivity and entail an RT-cost both in feature and conjunction search.

The Specificity of the Search Template Revisited: Evidence From Human Foraging

Tómas Kristjánsson, Katrín Justyna Alexdóttir and Árni Kristjánsson
Department of Psychology, University of Iceland, Iceland

According to several models of visual attention humans and other animals generate search templates that reflect our goals at a given moment and use such templates to guide their orientation within the visual environment. But how precise are such templates? When searching for a mushroom, will any mushroom do? This could lead to deadly mistakes. But an overly specific template might prevent us from finding a target in a dynamic, ever changing environment. Using a foraging task, where participants searched for two target categories, we measured how different target specificity affected the foraging performance. The results show that participants are faster the more specific the template is. Switching between target categories is not affected by template specificity but switching within categories is. The results suggest that with an unspecific target category we form more than one template, but that this does not affect switch-costs or the number of switches between target categories.

Multiple Identity Tracking: Unexpected Item Onset and Attentional Load

Michaela Porubanova[1], Maria Kuvaldina[2], Erica Geiger[1], Haaziq Walker[1] and Almara Kulieva[2]
[1]Department of Psychology, Farmingdale State College, NY, USA
[2]Department of Psychology, St. Petersburg University, Russia

Identification of an unexpected item (UI) in an attentionally demanding task depends on various factors. We used a modified multiple identity tracking task to test the effect of an UI onset on its identification. Target and distractor set size were manipulated as well. All items appeared on the display with a rate one per second, creating an anticipation of the next item to appear. When probed, observers identified the target more than both distractor and the UI. Target and distractor recognition was relatively stable regardless of load, but the UI recognition depended on task load. Interaction between the UI onset and the task load was found. When the load was low, observers were more likely to identify the UI once the attentional set was formed (after all targets appeared on the screen). But when the load was high, the UI was unlikely to be identified regardless of its onset. We discuss the results in the context of interaction between working memory load and satisfaction of search.

Abnormal Visual Search Among Population With Mathematical Learning Difficulties

Sharon Levy and Liat Goldfarb
Department of Learning Disabilities, University of Haifa, Israel

In conjunction visual search tasks, participants are asked to find a target that is defined by its bound features among distractors. The aim of this study was to examine this task among population with mathematical learning difficulties (MLD) which is characterized by deficits in understanding and processing of numbers and quantities. Since the ability to perform visual search and the perception of quantities might share a similar mechanism, we hypothesize that MLD would demonstrate a deficiency in visual search tasks. In the current study, adult participants with MLD and a matched control group preformed a quantity detection task as well as a conjunction visual search task. The results suggest that individuals with MLD not only have poorer quantity detection abilities but they also have general perceptual difficulties in the form of impaired visual search. Since visual search plays a major role in perceiving the world efficiently, the finding suggests that MLD has broad consequences for cognition.

Wednesday, August 29 – Symposia presentations

fMRI RESPONSES TO ADAPTATION OF VISUAL MAGNITUDES

Domenica Bueti
Cognitive Neuroscience, International School for Advanced Studies (SISSA), Italy

Several lines of research have suggested that time, space, number and other forms of magnitude processing originate from a common system in the brain. Supporting evidence has come in the form of behavioral interactions, lesions studies, and neuroimaging work. Many of these experiments have identified the parietal cortex as the core of this magnitude processing system. Indeed, a number of studies have used functional magnetic resonance imaging (fMRI) to identify topographic representations of different magnitudes within the parietal cortex. More recently, researchers have begun to explore how psychophysical adaptation paradigms change the neural representation of these magnitudes. This symposium will review recent advances in our understanding of how space, time, and number are represented in the brain. The emphasis will be on commonalities and differences in neural representations of magnitudes following psychophysical adaptation.

Mapping Time in the Human Brain

Domenica Bueti
Cognitive Neuroscience, International School for Advanced Studies (SISSA), Italy

Time is a fundamental dimension of everyday experiences. We can unmistakably sense its passage and adjust our behavior accordingly. Despite its ubiquity, the neuronal mechanism underlying the capacity to perceive time remains unclear In my talk, I will present a series of functional magnetic resonance imaging studies conducted at ultra-high-field (7 T), in which I show the existence in the medial premotor cortex and in the posterior parts of the left parietal lobule of chronomaps, that is, neural units tuned to different durations and orderly mapped in contiguous portions of the cortical surface. Through distinct experiments (with and without sensory adaptation) in which I change the sensory modality (visual and auditory) and the temporal context of the stimuli, I am able to define the functional properties of these chronomaps (e.g., modality and task specificity, perceived versus physical time representation).

Interactions Between Time, Number, and Action in Human Parietal Cortex

Maria Concetta Morrone
DAM, University of Pisa, Italy

The perception of space, time, and number are traditionally studied separately and thought to be independent dimensions. However, recent research suggests that these attributes are tightly interlinked: Event timing can be specific not only to the sensory modality but also tightly linked with space and with the intention to perform an action; visual numerosity and numerical calculation can be profoundly altered during shifts of gaze. Interestingly, both temporal duration and numerosity can change dramatically after visual adaptation. We have shown that numerosity can be decoded from the blood oxygenation level-dependent (BOLD) response of hIPS, when trained and tested either before or after adaptation, but not when trained before and tested after, and vice versa. Furthermore, the BOLD responses of this area encode small differences (30 milliseconds) in temporal separation between action onset and visual stimuli, reinforcing evidence for a shared representation of time, numerosity and action in IPS.

Neural Population Code in the Right Parietal Cortex Mediates Subjective Experience of Time

Masamichi Hayashi
Graduate School of Frontier Biosciences, Osaka University, Japan

Time is a fundamental dimension of our perception, action, and social interaction. However, it is still not clear how time is represented in the brain. Through a series of functional magnetic resonance imaging (fMRI) studies, I will show evidence that time is represented by a population code, and it is associated with our experience of time. First, using fMRI adaptation techniques, we show that repetition of the same stimulus duration produces a reduction of neural activity in the right inferior parietal lobule (rIPL), suggesting the existence of neural populations tuned for specific durations. Second, our fMRI decoding study shows that multi-voxel activity patterns in the rIPL carry duration information. Finally, using a psychophysical adaptation paradigm, we show that rIPL activity reflects the subjective experience of time rather than simply physical durations of stimuli. These findings suggest that our experience of time is mediated by duration-tuned neural populations in the rIPL.

Does Numerosity Adaptation Exist Without Duration Adaptation?

Andromachi Tsouli, Susan F. Te Pas, Serge Dumoulin and Maarten J. van der Smagt
Department of Experimental Psychology, Utrecht University, the Netherlands

We have previously shown that duration adaptation, like numerosity adaptation, alters numerosity perception. Here, we examined whether a low versus high numerosity adapter is perceptually associated with a short versus long duration adapter. Subjects indicated if a numerosity stimulus was under- or overestimated after numerosity adaptation using different durations. We found that different durations affect high numerosity adaptation but not low numerosity adaptation. Since a high numerosity stimulus combined with a long duration might be a stronger adaptation stimulus, we investigated whether this effect reflects the total adaptation time or adaptation to individual stimulus durations. We suggest that individual duration "events" drive the effect of duration adaptation on numerosity discrimination, while the effect of numerosity adaptation is driven by the total adaptation time. These results show that numerosity adaptation cannot exist without duration adaptation.

Spatiotopic Adaptation in Visual Areas

Eckart Zimmermann
Institut für Experimentelle Psychologie, University Düsseldorf, Germany

How the visual world remains stable across our frequent eye movements is a central problem in neuroscience. Visual adaptation provides an effective tool to study how visual space is reorganized across the execution of saccades. We combined behavioral visual adaptation with the paradigm of fMRI-adaptation. Subjects saw an oriented gabor patch for 3 seconds. The strength of adaptation aftereffects was measured after subjects performed a saccade. We found significant aftereffects at the retinotopic and the spatiotopic location. Significant clusters of neural adaptation were found in both conditions in contralateral visual areas V1-V4. In order to establish adaptation at the spatiotopic location, that is, in the hemisphere which was not adapted before the saccade, adapter activity must have been actively transferred. Further experiments confirmed the selectivity of transsaccadic adaptation. The results show that visual features are remapped in early visual areas across movements of the eye.

NEUROMODULATION AND CORTICAL PLASTICITY IN THE VISUAL CORTEX: LOCAL AND NETWORK EFFECTS

Grace Carolyn Alys Edwards and Federica Contò
CNCS Rovereto, Istituto Italiano di Tecnologia, Italy

Our symposium will go beyond classic local inhibition/excitation paradigms, to multi-method, network-wide stimulation protocols, applied to push the boundaries of stimulation efficacy. David Pitcher will show high-frequency transcranial magnetic stimulation (TMS) causes network wide functional connectivity modulation in face selective regions. Jennifer Steeves will demonstrate the effects of repetitive TMS to the visual cortex on GABA concentration. Gianluca Campana will focus on a range of transcranial random noise stimulation applications during motion tasks. Lorella Battelli will address the question of the length of brain and behavioral effects post-stimulation. Finally, Bart Krekelberg will present the neural consequences of transcranial current stimulation in the visual cortex of mice and non-human primates. The symposium aims to peak into the expansive method of neuromodulation and inspire fruitful conversation about application within vision research.

Mapping the Effects of Transient Cortical Disruption Across the Brain: Combining Thetaburst TMS and fMRI

David Pitcher
Department of Psychology, University of York, UK

Mapping the cortico-cortical connections of the functional brain networks that underpin human behavior is a fundamental challenge for neuroscience. The next conceptual gains in this area will come from a greater understanding of the causal interactions across these brain networks. Targeting a cortical area with transcranial magnetic stimulation (TMS), and measuring the disruptive effects across the brain with fMRI, offers a way to safely do this in a neurologically normal population. Results from these combined TMS/fMRI studies can be used to model the effects of traumatic brain injuries and brain disorders (e.g., autism) to improve understanding of how cortical disruption impacts the brain and behavior. In my talk, I will present a series of studies in which I have combined thetaburst TMS with fMRI to map the remote impact of disruption in the cortical network that underpins face perception in the human brain. These studies identify the causal connectivity across the face perception network.

Transcranial Random Noise Stimulation: Neural Mechanisms and Applications in Vision Research

Gianluca Campana[1], Rebecca Camilleri[2], Filippo Ghin[3], Beatrice Moret[1], Rita Donato[1], Chiara Milesi[1], Giuseppe Lo Giudice[1] and Andrea Pavan[3]
[1]Department of General Psychology, University of Padova, Italy
[2]Department of Psychology, University of Malta, Malta
[3]School of Psychology, University of Lincoln, UK

Weak currents applied to the skull (transcranial electrical stimulation - tES) are able to modulate neuronal excitability and plasticity of discrete cortical regions. Among the various techniques, transcranial random noise stimulation (tRNS) is the most recent one the neural mechanisms underlying the effects of tRNS, as well as the influence of stimulation parameters such as current intensity or frequency have not yet been completely uncovered Here, we show how the effects of tRNS on visual motion tasks depend not just on the stimulated site but also on the selected range of frequencies and on the intensity of the current that is applied. We also show how tRNS can be successfully used for boosting perceptual learning and transfer to untrained visual functions in participants with visual defects such as mild myopia or visual deficits such as amblyopia The putative mechanisms underlying the effects of tRNS on visual functions are discussed within the stochastic resonance framework.

Time-Dependent Neuromodulation of Large-Scale Attention Networks

Lorella Battelli[1], Sara Agosta[1], Florian Herpich[1], Federica Contò[1], Grace Carolyn Alys Edwards[1], Sarah Tyler[2] and Emily Grossman[3]
[1]CNCS Rovereto, Istituto Italiano di Tecnologia, Italy
[2]Department of Psychology, University of California, CA, USA
[3]Department of Cognitive Sciences, University of California Irvine, CA, USA

Interruption models of repetitive transcranial magnetic stimulation (rTMS) capitalize on the acute impact of brain stimulation, which decays over minutes. But rTMS also induces longer-lasting impact on cortical function, evident by the use of rTMS in clinical population. Modeling the persistent cortical dynamics induced by rTMS is complicated by the complex balance of excitation and inhibition among functionally connected networks. Nonetheless, it is these neuromodulations that are essential for the development of new modulatory technologies for translational applications. Late dynamics are consistent with complementary evidence from stroke patients for delayed improved attention abilities. I will show evidence of time-dependent, distributed strengthening of cortical connectivity that peaks tens of minutes following rTMS over the parietal cortex. Our data indicate that delayed cortical dynamics may persist as long as 90 minutes and have potential as an extended temporal window during which cortical plasticity may be enhanced.

Differential Effects of Single and Accelerated Low-Frequency rTMS to Visual Cortex on GABA Concentration

Jennifer Steeves and Sara Rafique
Centre for Vision Research, York University, Canada

Recently, we showed repetitive transcranial magnetic stimulation (rTMS) has potential for treatment in visual disorders by applying 1 Hz rTMS to visual cortex daily for 1 week to temporarily abolish disruptive visual phosphenes experienced by an individual who had previously suffered a visual cortex stroke. Here, we ask what are rTMS effects on excitatory and inhibitory neurotransmitters and how do they vary with different stimulation protocols? Specifically, we assess single versus accelerated sessions of offline rTMS to visual cortex on GABA+ and glutamate + glutamine (Glx) concentrations in healthy controls. There was no effect of a single session of rTMS however, following accelerated rTMS there was a significant reduction in GABA+ concentration lasting for up to 24 hours, and returning to baseline by 1 week post-rTMS. These data show potential for 1 Hz accelerated rTMS in therapeutic application to visual disorders where GABAergic mechanisms are implicated.

Neuromodulation of Visual Cortical Neurons by Transcranial Current Stimulation

Bart Krekelberg, Yinghua Liu, Jacob Duijnhouwer and Pierre-Olivier Polack
Center for Molecular and Behavioral Neuroscience, Rutgers University, NJ, USA

In transcranial current stimulation (TCS), small currents are applied to the head to modulate neural activity. TCS is gaining acceptance in applications to enhance learning and cognition or to gain insight into the causal roles of brain areas by modulating excitability, or entraining oscillations. However, little is known about the neural changes induced by TCS. Using two-photon imaging and multi-electrode recordings in the visual cortex of mice and nonhuman primates, we study the neural consequences of TCS and aim to address this gap in understanding. We find that even small currents modulate the activity of both pyramidal and interneurons. The modulation depends on the

frequency of the applied current, and the magnitude and sign of modulation varies substantially on a sub-millimeter scale. Such inhomogeneities may contribute to the variability of behavioral effects observed in humans and cast doubt on universal statements such as 'anodal tDCS increases excitability'.

THE INFLUENCE OF SECONDARY/ CORRECTIVE SACCADES ON MOTOR, VISUAL, AND COGNITIVE PROCESSING

Brent Parsons
Cognitive Neuroscience, SISSA, Italy

Saccades and smooth pursuit are often followed by smaller secondary eye movements thought to bring the eye closer to the intended target location. While there has been a resurgence in the study of fixational micro-saccades, very little is known about how these micro-saccades function in more naturalistic eye movement sequences. Recently, several investigators have uncovered novel properties of secondary saccades and their interaction with other visual and cognitive processes such as attention, memory, and perception. The findings have challenged the assumed error-correcting role of secondary saccades and demonstrated a number of independent factors guiding secondary saccade programming and production. The symposium will bring these researchers together to explore novel ways in which secondary saccades drive and impact our visual exploration of the world.

Execution of Corrective Saccades Affects Speed Perception

Karl Gegenfurtner[1], Alexander Göttker[1], Doris Braun[1] and Alexander Schütz[2]
[1]Department of Psychology, Giessen University, Germany
[2]Department of Psychology, Marburg University, Germany

Tracking a moving object is mainly done by using smooth pursuit eye movements, but additional corrective saccades are needed to correct for accumulating error signals. We investigated how these saccades influence the perceived speed of the moving target. During tracking retinal and physical motion become decoupled and the brain has to discount the eye movements to recover the speed of the moving target. We created situations where the same physical stimulus was tracked with or without additional corrective saccades, and measured their influence on perceived speed. We found that the execution of corrective saccades during pursuit initiation modifies how fast the target is perceived. While variations in eye velocity during pursuit did not have an effect, there was a correlation between average eye velocity and perceived speed for trials with corrective saccades. A model dynamically weighting a general eye speed signal and retinal velocity information can predict the data quite well.

Secondary Saccades Beyond Error Correction

Sven Ohl
Department of Psychology, Humboldt-Universität zu Berlin, Germany

Gaze shifts are often followed by a small secondary saccade that can quickly compensate for an error in primary saccade landing position. We recently highlighted that secondary saccades also occur after an accurate primary saccade—revealing a strong bias to follow the direction of the primary saccade for this subset of saccades. Here, we test whether processes underlying the programming of primary saccades affect this direction bias. In a prolonged post-saccadic fixation paradigm, participants generated saccades to endogenously or exogenously cued targets at an either close or distant eccentricity. On top of time-dependent error correction, we show an eccentricity-dependent bias of secondary saccades to follow the direction of the primary saccade for both endogenously and exogenously triggered saccades. We will discuss how secondary saccades provide a useful window into the visuomotor processes governing the transition from pre- to post-saccadic fixation.

Object Files Across Eye Movements: Previous Fixations Affect the Latencies of Corrective Saccades

Stefan Van der Stigchel, Jasper Fabius, Nathan van der Stoep and Martijn Schut
Department of Experimental Psychology, Utrecht University, the Netherlands

One of the factors contributing to a seamless visual experience is object correspondence (the integration of pre- and postsaccadic visual object information). Until now, studies on object correspondence have not taken previous fixations into account. In the present study, we investigated the influence of previously fixated information on object correspondence. To this end, we adapted a gaze correction paradigm in which a saccade was executed toward either a previously fixated or a novel target. During the saccade, the stimuli were displaced such that the participant's gaze landed between the target stimulus and a distractor. Participants then executed a corrective saccade to the target. The results indicated that these corrective saccades had lower latencies toward previously fixated than

toward nonfixated targets, indicating object-specific facilitation. We conclude that corrective saccades are executed on the basis of object files rather than of unintegrated feature information.

Rapid Alternating Saccades Reveal Biases in Secondary Saccade Programming

Brent Parsons[1] and Richard Ivry[2]
[1]Cognitive Neuroscience, SISSA, Italy
[2]Department of Psychology, UC Berkeley, CA, USA

In natural viewing, secondary saccades are typically part of an evolving and continuous saccade sequence. To study secondary saccades during saccade sequences, we introduce a simple, but novel task, rapid alternating saccades (RAS). Participants are asked to make a series of saccades as quickly as possible between fixed targets. Examination of secondary saccades under such conditions and across different experiments revealed novel factors guiding secondary saccade programming. Specifically, we discovered amplitude and direction driven biases in secondary saccade execution, a role for secondary saccades in inhibition of saccadic return, interactions between secondary saccades and concurrent manual action, plasticity of secondary saccades following RAS training, and correlations between secondary saccades and other eye movement metrics across individuals. The results challenge the assumed error correcting function of secondary saccades and provide a foundation for further exploration.

SEEING THINGS WITH DIFFERENT EYES: COMPARATIVE VISUAL PERCEPTION

Cinzia Chiandetti
Department of Life Sciences, University of Trieste, Italy

Thanks to both laboratory and field observations, the comparative study of nonhuman animals has provided scientists with insights on the fact that complex visual behaviors can be explained by simple processes and may be implemented by different solutions with similar functional effects. Despite embodied in extremely different nervous systems, universal mechanisms indicate a remarkable continuity in visual processing across species, making animal models of utmost relevance to inform heterogeneous fields of investigation on human vision, from neuroscience to psychology, biology, and artificial intelligence. Such hybridization between domains is essential to a mutual exchange of knowledge and methods: a unique occasion of contamination fostering novel research and advancements in our understanding of human perception. The symposium will also clarify whether certain visual functions are innate, shared, the result of specific selective pressures, or the effect of certain experiences.

Visual and Biomechanical Functions for Headbobbing in Birds

Niko Troje[1] and Leslie Theunissen[2]
[1]Department of Psychology, Queen's University, Canada
[2]Institute of Psychology and Education, Ulm University, Germany

Head-bobbing during terrestrial locomotion is observed in many bird species. However, the functional significance of this behavior is not obvious at all. Current theories focus on visual functions: A visual input that is free of self-induced optic flow during the hold phase, and increased flow velocities that improve signal-noise ratios for motion-parallax during the thrust phase of the head. I will critically review the evidence for these theories and, working with pigeons, I will present the results of experiments that failed to replicate earlier findings in their support. I will then discuss two new theories and present experimental support for them: The first concerns the possibility to monocularly estimate distance to objects and agents in situations in which normal motion parallax would not be able to provide information. The second is based on measurements of ground reaction forces during locomotion and suggests that head-bobbing reduces metabolic costs during walking.

Visual Statistical Learning in Honeybees

Aurore Avargues-Weber[1], Valerie Finke[1], Márton Nagy[2], Tunde Szabo[2], Adrian Dyer[3] and Jozsef Fiser[2]
[1]Centre de Recherches sur la Cognition Animale, Université Toulouse, France
[2]Department of Cognitive Science, Central European University, Hungary
[3]School of Media and Communication, RMIT University, Australia

The ability of developing complex internal representations of the visual environment is crucial to the emergence of humans' higher cognitive functions. Yet it is an open question whether there is any fundamental difference in how humans and other good visual learner species naturally encode aspects of novel visual scenes. We investigated how honeybees encode instinctively various statistical properties of different visual scenes presented in sequence. While after limited exposure, bees became sensitive to statistics of only elemental features (e.g., frequency of A) of the scenes, with more experience, they shifted to relying on co-occurrence frequencies of elements (frequency of AB) and lost their sensitivity to elemental

frequencies. However, the bees failed to show sensitivity to conditional probabilities (if A then B) contrarily to humans. Thus, humans' intrinsic sensitivity to predictive information might be a fundamental prerequisite of developing higher cognitive abilities.

Complex Visual Analysis of Socially Relevant Displays in Teleosts

Peter Neri
Laboratoire des Systèmes Perceptifs, École Normale Supérieure, France

Teleosts engage in diverse social activities, ranging from the highly gregarious zebrafish to the solitary Siamese fighting fish. When presented with conspecifics, these social tendencies produce stereotyped behaviours: zebrafish shoal towards their conspecifics, while fighting fish engage in aggressive displays. Under certain conditions, these behavioural patterns are sufficiently robust to support visual psychophysics and demonstrate complex visual capabilities that far exceed what is known about neural selectivity in these animals. For example, both species can discriminate between moving stimuli that are consistent as opposed to inconsistent with natural patterns, in the absence of low-level cues. These behavioural results indicate that complex visual analysis may be more cohesive and integrated than envisaged by hierarchical views, so that what are termed 'low-level' and 'higher-level' may be implemented by, and co-exist within, relatively small circuits.

Does Attention-Calling Alter the Perception of Social Interactions? A Comparison of Dogs and Wolves

Zsófia Virányi
Messerli Research Institute, University of Veterinary Medicine, Austria

For a decade, dogs were thought to outperform all other animal species in following human-given cues, such as pointing and gaze. More recent research has shown, however, that wolves can use human gestures to locate food as well as dogs, even if they need longer time to develop this skill. Current findings suggest that where dogs remain to be uniquely human-like is their sensitivity to human ostensive cues. As such, dogs follow pointing only if they were addressed beforehand, and follow human gaze only in communicative contexts, in contrast to wolves that readily follow also non-ostensive gaze. These findings are relevant not only for domestication theories reasoning about dogs' evolution but raise also interesting questions in regard to the perception of dogs and wolves of such social interactions. I will discuss various possible mechanisms how ostensive cues may affect dog behaviour, ranging from increase in attention to alteration of social perception or of the reasoning system used.

Can I Talk to a Squid? The Origin of Visual Communication Through the Behavioral Ecology of Cephalopod

Ryuta Nakajima
Faculty of Design, Kyushu University, Japan

The quest of modernity has come to its final phase in the form of postmodernism. Consequently, it is essential to investigate its effect and implication on the visual culture by asking existential questions such as: Why do we make images? Where do they come from and what is their primary function? In order to pursue these rather difficult questions, my work focuses on the adaptive coloration of cephalopods (squid, octopus, and cuttlefish) as comparative models that can code and remap visual information such as paintings, photographs, and videos. The genetically and evolutionally pure empirical data of the squid and cuttlefish not only uncover certain key information needed to understand the origin of visual communication, but also function as a catalyst that can redirect our culture away from the overstimulated hyperreality. This, in turn, can create a valuable interdisciplinary platform to discuss the current trends in both art and science.

RHYTHMS FOR PERCEPTION: HOW NEURAL OSCILLATIONS DETERMINE OUR PERCEPTUAL INTERPRETATION

David Melcher and Luca Ronconi
Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy

Research in the last decade has investigated the role of neural oscillations in the interpretation and organization of sensory inputs. One fundamental question is how different parameters of neural oscillations—such as amplitude, phase, frequency, scalp location/cortical generators, and the like—are related to the different complex problems that perception has to solve. These problems include (a) how sensory information is bound or separated across time or between sensory modalities, (b) the role of different oscillatory rhythms in attention and perception, and (c) how neural oscillations can be manipulated to influence perception. This symposium will bring together a group of scientists who have studied these questions, with the aim of providing novel insights into the rhythmic nature of visual perception and its importance for constructing conscious experience.

Rhythms in Perception: Action Planning and Behavioral Oscillations

Alessandro Benedetto and Maria Concetta Morrone
Department of Translation Research on New Technologies in Medicine and Surgery, University of Pisa, Italy

Action and perception are tightly coupled systems requiring strong coordination over time. However, how the brain achieves this close synchronization is still a matter of debate. Even a second before executing a voluntary action (hand or saccadic eye movement), visual sensitivity and criterion oscillate rithmically at different frequencies, suggesting separate mechanisms: sensitivity oscillates within the theta range (~6 Hz) and criterion in the alpha range (~10 Hz). Importantly, both oscillations are phase-locked with the action. Using ultra-high magnetic resonance imaging, we demonstrated that the rhythmic modulation is present in the blood oxygenation level-dependent response of V1, suggesting a motor influence at early stages of visual processing. Oscillations are a general principle of perception not confined to vision: Temporal order judgment between auditory and visual signals also oscillates in the alpha range, as for visual criterion. These results suggest a fundamental role of oscillations in binding perception with action.

Neuronal Oscillation Mediates Behavioral Oscillation in Visual Attention

Huan Luo
School of Psychological and Cognitive Sciences, Peking University, China

Recent studies have demonstrated periodicities in attentional behavioral performance, supporting that attention samples multiple locations/objects in a rhythmic manner. However, the neuronal mechanism underlying the dynamic selection remains unclear. We recently employed electroencephalogram/magnetoencephalography recordings in combination with a temporal response function (TRF) approach to probe neuronal response that specifically tracks each object and examined the spatiotemporal characteristics of attentional courses in multi-item visual scenes. Our results demonstrate crucial involvements of alpha-band and theta-band neuronal oscillations in temporally coordinating multiple locations, features, and objects, based on either top-down context or bottom-up saliency. Our results support that neuronal oscillations, in addition to being engaged in selective attention and perception and also essentially mediate the multi-item neural representation by flexibly and efficiently organizing resources in temporal dimension.

Shaping Brain Waves: An Information-Based Approach

Vincenzo Romei
Department of Psychology, University of Bologna, Italy

Noninvasive transcranial brain stimulation (NTBS) techniques have prompted a paradigm shift in the study of brain functions in human behaviour from correlation to causation. Mimicking endogenous brain oscillations through NTBS protocols has allowed shaping both amplitude and phase of the targeted oscillation, when the frequency of stimulation matches the endogenous oscillatory frequency, ultimately impacting behaviour. I will show how information-based approaches of NTBS to the study of brain oscillations can further our understanding of their functional relevance by manipulating a third component kept constant in previous research: the endogenous frequency itself. By externally imposing slower or faster frequencies than the endogenous frequency, we can shape behaviour in expected directions. Finally, I will show how manipulation of functional connectivity between interconnected areas induces modulation of interareal oscillatory activity, allowing causal assessment of their function.

Temporal Windows in Perception and Their Link With Neural Oscillations

Luca Ronconi[1], Nikolaas Oosterhof[1], Niko Busch[2], Claudia Bonmassar[1], Daniel Baldauf[1] and David Melcher[1]
[1]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy
[2]Institute of Psychology, University of Münster, Germany

Growing evidence suggests a role of neural oscillations in determining temporal aspects of perception. Here, we present converging evidence of a direct link between ongoing oscillations and the sampling of visual information over time. First, we show that performance on temporal integration/segregation tasks can be modified by the use of pre-stimulus sensory entrainment within a range of frequencies spanning alpha and theta bands (6–12 Hz). Second, we report electroencephalogram and magnetoencephalography evidence that single-trial pre-stimulus oscillatory phase can be used to accurately decode participants' temporal integration/segregation. The best decoding frequency varies as a function of the specific temporal window involved, with shorter windows associated to alpha (8–12 Hz) and larger windows associated to theta (6–8 Hz) oscillations. Overall, these findings suggest a precise mapping between oscillatory rhythms and temporal windows in perception.

Alpha Frequency Shapes Temporal Integration and Is Guided by Top-Down Control

Jason Samaha[1], Andreas Wutz[2], David Melcher[3] and Bradley Postle[4]
[1]Department of Psychology, University of Wisconsin-Madison, WI, USA
[2]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, MA, USA
[3]Center for Mind and Brain Sciences, University of Trento, Italy
[4]Psychology and Psychiatry, University of Wisconsin-Madison, WI, USA

Evidence suggests that alpha oscillations (8–13 Hz) shape the temporal structure of visual processing, renewing interest in the hypothesis that alpha cycles reflect temporal integration windows. We present new evidence for this hypothesis by showing that individual differences in two-flash fusion thresholds are linked to variation in alpha frequency. Furthermore, cross-trial fluctuations in alpha frequency are predictive of two-flash discrimination, indicating that alpha frequency may vary dynamically within an individual. To test whether this variation can be modulated by top-down control, we compared a task that encouraged temporal integration to one that encouraged segregation. We found that alpha frequency decreased when task demands required integration compared with segregation. These results indicate a link between the alpha rhythm and temporal windows of perception and suggest that alpha frequencies can be modulated by task demands to regulate the temporal resolution of vision.

Neural Oscillations as Time Metrics

Virginie van Wassenhove
Cognitive Neuroimaging Unit, CEA/INSERM, France

It is undeniable that periodic processes are fundamental features of natural systems, and it remains controversial that brain rhythms are functionally significant for perceptual processing or reflect an underlying cognitive architecture. I will discuss how neural oscillations may acquire a basic functional role by modulating the otherwise passive serial ordering of information processing in the brain. For this, I will draw examples from our recent work on temporal order perception in multisensory contexts using entrained and non-entrained paradigms with magnetoencephalography. I will further discuss whether neural oscillations solely provide a temporal architecture for information processing, or whether/and also, naturally provide time metrics for our awareness of time.

ECVP 1978-2018 – "NOW WE ARE 40"

Brian Rogers
Department of Experimental Psychology, University of Oxford, UK

The purpose of this symposium is to review and discuss the changes that have occurred in the field of perception over the last 40 years. The six contributors have been asked to highlight the most significant findings and developments in their own area of research and to comment on how research on perception has changed from an emphasis on the low-level mechanisms of contrast, colour, depth and motion perception to topics such as perception and action, object properties, attention and perceptual organisation. The techniques used to study perception have also changed from sine wave grating patterns displayed on oscilloscope screens to synthetic images and virtual reality displays, and from single cell recordings to functional magnetic resonance imaging scanning and tractography. Finally, contributors have been asked to discuss the changes in the underlying theoretical and philosophical assumptions that influence the topics chosen for study and how the field of perception is likely to change over the next 40 years.

The Lost Realms of Stimulus Space

John Mollon
Department of Psychology, University of Cambridge, UK

In 1978, computer-controlled colour displays were only a dream, and every visual scientist had training in the fine art of aligning a Maxwellian-view optical system. Only in few labs does that antique skill survive, but by embracing modern displays, the visual scientist has surrendered back to nature the large tracts of stimulus space that can be explored only by Maxwellian view. These are the realms that require a colorimetric purity or an intensity or a temporal frequency or a point of pupil entry that cannot be achieved with a graphics display. Yet in the lost realms of that pre-Adamite world – so the greybeards tell – are to be found fabulous Paradoxes, Anomalies and Curiosities (as well as Radiation Hazards). At the Marburg meeting, I described a strange 'deferred saturation', in which the threshold for short-wave flashes rises slowly (but substantially) during the first seconds of exposure. A related effect is 'transient tritanopia of the second kind', which has recently been modelled by Stockman and collaborators. I review these largely neglected phenomena.

Stereoscopic Vision: From Positional Disparities to Global Analysis

Barbara Gillam
Department of Psychology, University of New South Wales, Australia

Wheatstone first showed vivid "stereo" depth based on binocular positional disparities. Gradients of such disparities produce stereo slant, which can be slow to emerge and exhibit strong horizontal/vertical anisotropies. However, gradients of relative disparity, such as occur between abutting surfaces placed in a "twist configuration," produce fast and accurate perceived slant. Neither directional anisotropies nor the superiority of relative disparity gradients are adequately explained by theories of stereo slant based on individual disparity detectors. They require a more global analysis. Challenges to stereo theory are also posed by the insight of von Szily that monocular regions in binocular views are not treated as noise but have a depth predicted by the binocular geometry of occlusion relations. Phantom occluding surfaces "accounting for" monocular regions may be seen.

From Gratings to Gestalts: Some Reflections From 40 Years of ECVP

Johan Wagemans
Brain and Cognition, KU Leuven, Belgium

When ECVP started in 1978, sensory psychophysics and single-unit recordings strongly dominated the field. Psychophysicists were testing all kinds of hypotheses derived from the spatial channels model of vision using detection and discrimination thresholds, sensitivity, adaptation, summation, and so forth, preferably with sine- or square-wave gratings. Electrophysiologists were characterizing the tuning functions of single-cell responses of cats and monkeys to approach the neural codes more directly. This reductionist approach did not leave much room for richer perceptual phenomena that interested the Gestalt psychologists such as figure-ground organization, configural effects, perceptual multistability, shape, and object perception. These topics have gradually become more prominent again in recent decades, although mainstream vision science still has not grown out of its neuroreductionist framework. Phenomenology and neural dynamics might provide guidance toward a proper Gestalt revival, beyond a rather shallow focus on appearance and more naturalistic stimuli.

From Gabor Patches to Natural Scenes

Peter Neri
Laboratoire des Systèmes Perceptifs, École Normale Supérieure, France

Recent conceptual and technological developments have prompted questions that were not of immediate concern to most vision scientists at the turn of the century, with greater emphasis on how vision operates under natural conditions. Those who attended ECVP in Marburg knew well that the tests routinely performed in their laboratories represented dangerous simplifications of complex perceptual phenomena. At the same time, they were understandably unwilling to compromise on rigour: A Gabor patch may not be representative of a natural scene, but it supports well-controlled quantitative characterization. It was justifiably felt that the protocols/techniques successfully utilized with simple stimuli, when applied to natural scenes, would become fraught with confounds. I will attempt to summarize the main elements that have made it possible to resolve this impasse and deploy quantitative tools to natural vision, while retaining the fine control demanded by psychophysical standards.

From One to Many: Looking at Perception Across Modalities

Lore Thaler
Department of Psychology, Durham University, UK

Some of us may have encountered a blind person walking confidently while making clicking noises with their mouth, avoiding obstacles well before they are within reach of the long cane. It turns out that they are using echolocation, the same skill that bats use. Only within the last decade has human echolocation research made it into the wider scientific awareness. As far as I am concerned, human echolocation in its own right is a fascinating research subject. But in my talk, I will also argue that investigation of other modalities (for which echolocation is an example) is essential for understanding vision. To this end, I will describe neuroimaging evidence suggesting that traditional 'visual' brain areas are involved during echolocation in blind echolocation experts, and that this activation appears to be feature-specific, much in the way that visual activations are feature-specific. I will also describe behavioural evidence suggesting that echolocation may attain certain 'visual' functionality. I propose that finding out about the principles driving such convergence between vision and other modalities such as echolocation will change how we think about vision.

From Gratings to Goop: New Directions and Approaches in Visual Perception Research

Roland Fleming
Department of Experimental Psychology, University of Giessen, Germany

Many of the central questions of visual perception research are timeless: Why do things look the way they do? How does the visual system overcome ambiguities? How do we see in three-dimensional (3D) and identify objects and their properties by sight? While these core questions certainly existed 40 years ago, our methods and approaches have evolved enormously in the intervening years. Here, I focus on advances in the perception of surfaces and objects, especially the perception of 3D shape and material properties. I will discuss how tools like photorealistic computer graphics, crowd sourcing and machine learning make new research approaches possible. I will describe how my research group has tried to use these tools to measure and model shape-from-shading and the perception of gloss, softness and viscosity. I will suggest that we are progressing, gradually, from empirical characterisations of detection and discrimination to detailed process models of subjective visual appearance.

Imitation in Autism: Exploring the Impact of Attention Instructions During Action Observation

Emma Gowen
Department of Biology, Medicine and Health, The University of Manchester, UK

Voluntary imitation involves observing then copying an action and is important for learning actions from others and facilitating interpersonal interactions. How closely an imitated action reflects the observed action can provide information on a persons ability to extract kinematic information used to predict others actions. Studies show that autistic individuals imitate action kinematics less accurately then non-autistic individuals, suggesting reduced ability to extract kinematic details. For example, they modulate the vertical amplitude of their movement less than non-autistic individuals when imitating movements of different heights. Here, I present results demonstrating that autistic adults increase modulation of imitated movements following instructions to pay attention to the observed movement. This indicates that altered attention to the observed action contributes to differences in imitation behaviour and that attention could be important for action perception in autism.

PERCEIVING OTHERS, INTERACTING WITH THEM: NEW PERSPECTIVES IN ACTION OBSERVATION RESEARCH

Antonella Maselli
Neuromotor Physiology Lab, Fondazione Santa Lucia, Italy

The ability to understand others' behavior from action observation is critical for humans when interacting with their physical and social environment. Understanding other people's behavior indeed allows people to derive the goals guiding others' actions and respond appropriately to them, often in an anticipatory manner. The aim of this symposium is to provide an integrative view on recent advances in our understanding of the psychological and neural processes underlying others' action perception. Researchers from developmental psychology to human brain imaging studies will discuss new and related evidence in the ability to perceive and make predictions about others' actions with a specific focus on implications for actual human interactions in daily life. Experimental data from infants, normotypical and clinical populations, will be presented and discussed in the context of a general model of the role played by action perception in interpersonal interaction.

Contextual Effects in Perceiving Other's Actions: A Transcranial Magnetic Stimulation Approach

Lucia Amoruso
BCBL, Spain

People's actions constitute a powerful source of information which enables us to socially interact on a daily basis. A critical aspect that has so far been neglected concerns the context-embedded nature of action perception. Indeed, body movements are not perceived in isolation but with objects, actors, and the relationships among them "gluing together" into a unifying scene. In this talk, I discuss recent work from my group using transcranial magnetic stimulation, showing that top-down contextual cues profoundly shape motor resonance with different mechanisms (facilitation vs. inhibition) and timings (early vs. late). These findings challenge previous ideas about how we perceive other's actions by showing that motor resonance is not an entirely automatic process and suggest broader, more flexible processing from high-level contextual representations. The implications of these findings are further considered in light of a wider brain network including temporal and prefrontal areas.

Developmental Mechanisms for Action Prediction: From Infants to Adults

Janny Stapel[1], Sabine Hunnius[1], Benjamin Koch[2], Marlene Meyer[3] and Harold Bekkering[1]
[1]Donders Centre for Cognition, Radboud University Nijmegen, the Netherlands
[2]Department of Psychology, Uppsala University, Sweden
[3]Department of Psychology, University of Chicago, IL, USA

Acquiring the ability to predict others' actions may form an important stepping stone in social-cognitive development. I will present three eye-tracking experiments studying the development of predicting others' actions. Results from the first two studies indicated that the actor's kinematics are important for action prediction from infancy on. Furthermore, a clear correspondence was found between the ability to predict an action and the ability to perform the action. Motor development can hence be critical for social-cognitive development. In the third study, 13-month-old participants had the opportunity to use either the gaze or the movements of the actor's hand to predict her reaching actions, as her gaze naturally preceded her manual actions. Infants were found to rely on hand movements rather than on the actor's gaze in their predictions. Combined, these studies demonstrate that action simulation might underlie action prediction already in infancy and beyond.

The Role of Visual Information During Joint Action

Cordula Vesper
Department of Linguistics, Cognitive Science and Semiotics, Aarhus University, Denmark

How is perceptual information used when two or more people coordinate their actions towards a common goal? In contrast to pure observation cases, acting with others typically requires a high level of coordination and co-actors consequently adapt to each other's actions with high temporal and spatial accuracy. How do people achieve such precise coordination? Based on data from motion-tracking experiments, in which the availability of visual information between interaction partners is systematically modulated, I will discuss evidence (a) that co-actors actively enhance the availability of visual cues to support prediction processes for the partner and (b) that in the absence of visual information, general action strategies can compensate for missing online feedback.

Sensorimotor Communication Strategies for Improving Interactive Skills

Francesco Donnarumma
ISTC, CNR, Italy

During joint actions, coactors engage in various forms of sensorimotor communication, that is, communication signals sent on the same (motor) channel of to-be-performed action. A specific form of sensorimotor communication is signaling, obtained when an agent modifies his own behavior to make it more discriminable by a coactor. We implement a computational model comprising two main mechanisms: (a) an action prediction mechanism that amounts to a (Bayesian) process embedded in probabilistic graphical models in which the agents' cognitive states are described by probability distributions; (b) a signaling component that amounts to the intentional shaping of one's own actions, in such a way that they become easier to disambiguate from alternatives. Our simulations show that online interactions can be efficiently performed by a perceiver agent (using prediction mechanisms) and a performer agent (using signaling mechanisms).

WHAT INDIVIDUAL DIFFERENCES TEACH US ABOUT VISION: GOING BEYOND SIMPLE CORRELATIONS

Pieter Moors[1] and Michael H. Herzog[2]
[1]Brain and Cognition, KU Leuven, Belgium
[2]Brain Mind Institute, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

The past decade has seen rapidly growing interest in using individual differences in visual data to identify and better understand visual processes. This contrasts with an experimental paradigm in vision science which has treated individual variability as a nuisance to be averaged away rather than considered. Individual differences are frequently studied by correlating measurements of different visual phenomena or tasks, elucidating whether they are driven by common or distinct mechanisms. This symposium will go beyond this approach, by focusing on experimental, statistical, and modeling approaches that transcend some of its limitations, and by showing applications of these enhanced approaches to specific topics.

Using Individual Differences to Infer Visual Mechanisms

Jenny Bosten[1] and John Mollon[2]
[1]School of Psychology, University of Sussex, UK
[2]Department of Psychology, University of Cambridge, UK

Individual variation, often neglected in the analysis of psychophysical data, has the potential when used effectively to reveal the action of underlying visual mechanisms. By observing correlated variation, individual differences can also be used to unify accounts of visual traits at different 'levels', for example, molecular, physiological and cognitive. To illustrate these points, I draw on examples, particularly from the PERGENIC study of individual variation in perceptual traits. I focus particularly on factor analysis and genome-wide association as methods used in individual differences research, exploring some of their strengths and limitations for vision science.

Decoding Perceptual Representations From Individual Differences

Kara J. Emery[1], Vicki J. Volbrecht[2], David H. Peterzell[3,4] and Michael A. Webster[5]
[1]Department of Integrative Neuroscience, University of Nevada, Reno, NV, USA
[2]Department of Psychology, Colorado State University, CO, USA
[3]School of Optometry, University of California Berkeley, CA, USA
[4]Department of Psychology, John F. Kennedy University, CA, USA
[5]Department of Psychology, University of Nevada, Reno, NV, USA

Both visual space and color space are three dimensional, but to what extent do they share analogous perceptual representations? We measured individual differences in color appearance in color-normal observers, using a standard "hue scaling" task in which observers judged the proportion of red/green and blue/yellow in each hue. Factor analyses of these settings reveal multiple, narrowly tuned processes, arguing against a representation of hue in terms of two underlying chromatic axes. To test for corresponding effects for space, we developed a "motion scaling" task, in which observers rated the proportion of left/right and up/down motion in moving dots. Factor analyses of these settings instead point to global processes consistent with a metrical code in terms of the cardinal spatial axes. These results suggest that while the stimuli for color and motion share a common dimensional structure, the perceptual representations of color- and motion-defined space are fundamentally different.

The Individual Structure of Visual Space

Michael H. Herzog[1], Aline F. Cretenoud[1], Gregory Francis[2], Albulena Shaqiri[1] and Lukasz Grzeczkowski[3]
[1]Brain Mind Institute, Ecole Polytechnique Fédérale de Lausanne, Switzerland
[2]Department of Psychological Sciences, Purdue University, IN, USA
[3]Department Psychologie, Ludwig-Maximilians-Universität München, Germany

Common factors are ubiquitous. First, we show that, however in vision, correlations of performance in similar paradigms are low even though test–retest reliability is high. Second, one might expect that correlations increase with increasing age because of the common factor of age. However, this is not true. Third, we found significant correlations between the Ebbinghaus and Ponzo illusion, but this relationship was the only significant correlation out of all 16 comparisons. Surprisingly, we found a significant link between the Ponzo illusion and both mental imagery and cognitive disorganization. Almost all other correlations between illusions and personality were not significant. Fourth, we found high correlations between 19 versions of the Ebbinghaus illusion, suggesting that there are extremely specific factors. Beyond these factors, vision is highly individual except for rare common causes, which unfold in a complex space and do not easily map on common explanations in vision.

Order-Constrained Inference to Study Individual Differences in Perceptual Organization

Pieter Moors and Johan Wagemans
Brain and Cognition, KU Leuven, Belgium

Vision scientists have become more and more interested in relating individual differences in visual processing to psychopathology, culture, or experience. An assumption underlying these studies is that such measures reflect genuine interindividual variability rather than variability due to trial noise. Here, we introduce the framework of order-constrained hierarchical inference which allows us to quantify the evidence for the presence of individual differences. We take the well-known global precedence and global/local interference effects as a case study. In a data set of about 260 participants, we observe that there is evidence for individual differences in global precedence. To the contrary, global/local interference seems to be stable across observers. These findings imply that variability in any experimental effect cannot just be taken for granted. Ideally, the presence of meaningful interindividual variability should first be established before relating it to other variables.

From Human Variability to Visual Mechanisms: Some Uses and Abuses of Factor Analytic Methods in Vision Science

David H. Peterzell[1,2]
[1]Department of Psychology, JFKU, CA, USA
[2]Department of Vision Science, UC Berkeley, CA, USA

Estimates of the number and tuning of visual mechanisms have been made by factor analyzing individual differences. Published factors abound for color, contrast, stereopsis, faces, and the like, with potential for discoveries in a trove of new and unmined archival data. The factors found in correlation matrices, principal component analysis (PCA) and factor analysis (FA) may represent real underlying mechanisms, or they may just be efficient summaries, artefacts, or fictions. That they are real is a hypothesis which these methods can suggest but for which validation is required. I review some successes in confirming, testing, and creating models, and examine some confusing or misleading results, and limitations. I review some methods for identifying "real" processes: (a) 'intuitive' factor analysis, or 'seeing' factors in data without statistics, (b) confirmatory vs. exploratory analyses, (c) ways to estimate mechanism sensitivity from factors, (d) Monte Carlo and live simulations of models, and (e) factor replication strategies.

Large-Scale Individual Differences in Visual Appearance and Their Dynamics Over Time and Space

Mark Wexler
Laboratoire Psychologie de la Perception, CNRS & Université Paris Descartes, France

Most individual differences in low- to mid-level visual appearance that have been reported are both small (many can be explained by small variations in priors or biases) and stable over time. In contrast, I will report on a new type of individual difference in the appearance of several families of visual stimuli that is large scale (in a sense that I will explain) and that occasionally undergoes large fluctuations over time. These robust but maleable individual differences must be manifestations of persistent states of the nervous system. I will present studies showing that these underlying states can exist and evolve in spaces with different numbers of dimensions for different types of stimuli. Other studies show that the states can be non-uniform over the visual field, with spatio-temporal dynamics reminiscent of physical fields. More generally, these results show how individual differences can be used to probe fundamental properties of vision.

VISUAL CONTROL OF ACTION IN COMPLEX SENSORIMOTOR SITUATIONS

Dimitris Voudouris
Department of Experimental Psychology, Justus Liebig Universitat Giessen, Germany

Humans can successfully interact and move within their dynamic environment through a large movement repertoire. Vision is a critical aspect for this as it provides key sensory information for movement planning and control. Gaze is primarily shifted proactively to relevant positions for the upcoming movement, and samples visual information from positions around the currently executed movement to monitor its success. But what aspects are critical for these gaze shifts and how is the obtained visual information deployed after its sampling? In this symposium, we will present recent insights with a twofold direction. First, we will elucidate the factors underlying gaze guidance to certain positions before and during complex movements. Second, we will emphasize and focus on how the obtained visual information is valued and deployed to plan and control complex movements.

Eye Movements in Grasping

Dimitris Voudouris[1], Jeroen B. J. Smeets[2], Katja Fiehler[1] and Eli Brenner[2]
[1]Department of Experimental Psychology, Justus Liebig Universitat Giessen, Germany
[2]Department of Human Movement Sciences, Vrije Universiteit Amsterdam, the Netherlands

Visual information is critical for the control of goal-directed hand movements. When grasping an object, people bring their digits almost simultaneously to two different positions on its surface. However, they can only direct their gaze to one position at a time. Most studies show that people fixate around the time of the grasp near their index finger's end point. We will present recent, puzzling findings about where people look when grasping. Several factors seem to influence fixations to some extent, such as how much the end points are occluded, accuracy demands, and gaze location before the grasping movement. We further suggest that fixation may also be determined by where the action following the grasp will happen. Importantly, we show that fixations differ systematically between participants, and even between repetitions of the same task under different circumstances by the same participants, suggesting that gaze biases may mainly depend on many factors beside the digits' end points.

The Contribution of Visual Information to Upper Limb Movements in Older Adults

Rachel Coats
Department of Psychology, University of Leeds, UK

Visuomotor coordination is affected by aging, especially so when task difficulty is increased. I will present data examining how both age and task difficulty affect eye–hand coordination during upper limb tasks. Data from a recent multiphase prehension experiment where 12 older adults (mean age = 74) and 11 younger adults (mean age = 20) moved objects from one location to another will be discussed. Older adults took longer to complete their hand movements and reached lower peak velocities than the younger adults. Group differences were most apparent when task difficulty increased: During pickup, older adults preferred to make an eye movement to the next target as soon as possible, but spent longer fixating the current target during placement, when accuracy requirements were higher, suggesting they employed a task-dependent eye movement strategy. I will end by outlining how upper limb movements are affected when visual information on hand position is removed.

Gaze Control for Natural Action

Mary Hayhoe and Jonathan Matthis
Center for Perceptual Systems, The University of Texas at Austin, TX, USA

In natural behavior, humans make continuous sequences of sensory-motor decisions to satisfy current goals, and the role of vision is to provide the relevant information to control action decisions in order to achieve those goals. I will review the factors that control gaze in natural action decisions, including the rewards and costs associated with those decisions, uncertainty about the state of the world, and prior knowledge. Visual computations are often highly task-specific, and evaluation of task relevant state is a central factor necessary for optimal action choices. This means that information about natural action contexts is important for a full understanding of the factors controlling action decisions. I will discuss how these factors control visual sampling strategies in the context of walking both in immersive virtual environments and walking in outdoor terrains.

Gaze Adaptations to Peripheral Visual Field Loss During Locomotion

Colas Authié
Streetlab – Institut de la Vision, France

Peripheral visual loss impairs both visual perception and motor control. It damages spatial localization, affects postural control, and could lead to unintentional bumps and orientation errors. Subsequently, patients suffering from severe peripheral field loss walk slowly and limit their independent travel. However, they should adapt their behavior to compensate their deficit, and develop new sensorimotor strategies. In a series of experiments, we explored this hypothesis with retinis pigmentosa patients performing goal directed locomotion and trajectory reproduction. The loss of peripheral vision did not alter gaze anticipation behavior. However, we identified several changes in gaze strategies, including a more extensive exploration, mostly on the ground, and specific scanpaths. These adaptations allow patients to detect changes in spatial configuration, collect information for self-motion, and update the postural reference frame and egocentric distances to environmental objects.

Understanding Vision and Action Through Computation

Constantin Rothkopf
Department of Psychology, TU Darmstadt, Germany

Active vision has long put forward the idea that sensing and acting are inseparable, especially when considering naturalistic extended behavior. Further support for this idea comes from theoretical work in optimal control and reinforcement learning, which demonstrates that sensing, planning, and acting in sequential tasks can only be separated under very restricted circumstances. We present experimental evidence together with computational models of human visuomotor behavior in tasks ranging from psychophysical detection tasks with complex probabilistic structure to the interception of fly balls and visuomotor navigation in virtual reality (VR). Along the way, we will touch topics such as the heuristics hypothesis and the learning of visual representations. The connecting theme will be that, from the switching of visuomotor policies in response to changing task-constraints down to cortical visual representations in V1, action and perception are inseparably intertwined in an ambiguous and uncertain world.

WHAT ARE EYE BLINKS GOOD FOR? PERCEPTUAL, OCULOMOTOR, AND COGNITIVE EFFECTS OF EYE BLINKS

Gerrit Maus
Department of Psychology, Nanyang Technological University, Singapore

Eye blinks last up to 300 milliseconds and occur 20 times per minute, far more often than necessary for maintaining the corneal tear film. What justifies sacrificing so much of the visual input? This symposium focuses on the consequences of blinks for neural processing, perception, eye movements and higher cognitive processes. Perceptually, we rarely notice our own spontaneous blinks. Transients caused by blinks are suppressed perceptually and in higher cortical areas. Duration judgements during blinks seem to underestimate elapsed time. Nevertheless, blinks may support important oculomotor and cognitive functions: They help maintain stable gaze direction by recalibrating oculomotor commands, and they may 'reset' visual processing and attention. Furthermore, blink control seems to be aware of high-level stimulus aspects, such as saliency, semantic and social contents of a scene. Each contribution in this symposium will present recent findings on the functions and consequences of eye blinks.

Eye Blinks, Perception, and Prediction

Tal Golan[1], Shany Grossman[2], Ido Davidesco[3], Meir Meshulam[2], David M. Groppe[4], Pierre Mégevand[5,6], Erin M. Yeagle[5,6], Matthew S. Goldfinger[5,6], Michal Harel[2], Lucia Melloni[7,8], Charles E. Schroeder[9,10], Ashesh D. Mehta[5,6], Leon Y. Deouell[1] and Rafael Malach[2]
[1]The Edmond & Lily Safra Center for Brain Sciences, The Hebrew University of Jerusalem, Israel
[2]Department of Neurobiology, Weizmann Institute of Science, Israel
[3]Department of Psychology, New York University, NY, USA
[4]The Krembil Neuroscience Centre, ON, USA
[5]Hofstra Northwell School of Medicine, NY, USA
[6]Feinstein Institute for Medical Research, NY, USA
[7]Max Planck Institute for Brain Research, Germany
[8]New York University, NY, USA
[9]Columbia University College of Physicians and Surgeons, NY, USA
[10]Nathan Kline Institute, NY, USA

We usually fail to notice our own eye blinks even though they cause a strong retinal interruption. Inferring from previous works on conscious perception, one may expect high-level visual representations to be "turned off" during visible stimulus-disappearances but not during spontaneous blinks. We tested this prediction using intracranial recordings in human patients. High-level visual cortex showed no filling-in of occluded content and furthermore, it displayed suppression of blink-related transient positive responses. In a follow-up functional magnetic resonance imaging study, we tested also external darkenings triggered by button presses, mimicking blinks' motor-sensory coupling. These self-initiated darkenings slightly deactivated high-level visual cortex, similarly to blinks, whereas unpredictable darkenings activated the same regions positively. These results argue against neuronal filling-in of blinks and suggest an involvement of general-purpose predictive computation in blink suppression.

Visual Continuity and Alterations in Time Perception During Blinks

Marianne Duyck, Thérèse Collins and Mark Wexler
Laboratoire Psychologie de la Perception, Université Paris Descartes & CNRS, France

Eye blinks strongly attenuate visual input, yet we perceive the world as nearly continuous. How this continuity is achieved remains a fundamental and unsolved problem. Continuity cannot rely on contrast suppression, because suppression is insufficient to mask the decrease in luminance. We put forward a new hypothesis: Visual continuity can be achieved through shortening of perceived durations. We found that within-blink darkness is perceived as 50% to 70% briefer than artificially produced darkness immediately preceding or following the blink. Stimuli interrupted by real or simulated blinks were perceived as briefer than continuous stimuli. However, the decrease in duration depended on the duration of simulated, but not on real, blinks. These profound modifications in temporal processing during blinks, possibly analogous to those around saccades, lend support to the hypothesis that visual continuity across blinks is achieved with the help of temporary modifications in time perception.

Blinks Reset Gaze Control and Attention

Gerrit Maus
Department of Psychology, Nanyang Technological University, Singapore

Blinks completely disrupt the stream of inputs from the retina and introduce instabilities in gaze direction, yet perception remains continuous throughout spontaneous blinks. To help maintain stability, blink-related eye movements anticipate and correct for cumulative gaze position errors across blinks, effectively recalibrating gaze direction with every blink. An open question is whether blinks similarly reset perceptual or attentional processes. Here, we show some behavioural evidence that blinks may cause an attentional reset. In rapid serial visual presentation tasks

that require identification of a target in a rapid stream of distractors, we found a boost in identification performance time-locked to the last blink. A blink made subjects more likely to identify a target occurring shortly after the blink, pointing to a potential function of blinks resetting attentional processes. Both findings indicate that blinks may provide important resets to visual processing.

Saliency and Surprise Revealed by Spontaneous Eye Blinks

Yoram Bonneh
Department of Optometry and Vision Science, Bar-Ilan University, Israel

Spontaneous blinking is known to serve an important physiological function, but recent evidence links it with cognitive processes. In this talk, I will show that spontaneous blinking is controlled by an automatic and precise mechanism, tightly linked to perceptual saliency and surprise. In a set of experiments, observers viewed passively a slide show of flashed visual and auditory stimuli at a regular 1 Hz rate. We found that spontaneous blinks, like microsaccades, showed a stimulus-dependent inhibition, with shorter inhibition for more salient stimuli, but longer inhibition and more blinking for "surprise" in the identity and time of items in a sequence, proportional to a "prediction error" based on the preceding events. These results point to a common mechanism that presumably turns off oculomotor events while processing previous stimuli. Upon release from inhibition, blinks could provide a transient stimulation for global synchrony, and a "reset" signal following a prediction error.

Cognitive and Social Functions of Spontaneous Blinks

Tamami Nakano
Graduate School of Frontiers Biosciences, Osaka University, Japan

People spontaneously generate blinks every 3 seconds, but the cognitive and social functions of spontaneous blinks remain unknown. We found that spontaneous blinks were synchronized between people at the implicit attentional breakpoints of movies. In association with these blinks, cortical activity momentarily decreased in the dorsal attention network, but increased in the default mode network. We speculate that spontaneous blinks are involved in attentional disengagement from the external world by switching activity between opposing neural networks. Spontaneous blinks also play an important role in social communication. In face-to-face communication, a listener's blinks are synchronized to the speaker's blinks with a latency of 0.5 seconds at breakpoints in the speech. By contrast, adults with autism spectrum disorders did not show any blink synchronization with the speaker. These results suggest that blink synchronization sharply reflects the quality of social communications.

NUMERICAL VISION

Ben Harvey
Department of Experimental Psychology, Utrecht University, the Netherlands

Recent research demonstrates that the number of objects in an image (numerosity) is an important parameter for visual perception and the brain's visual system. This symposium explores links between numerical vision and the central topics of vision science. These include links to various visual functions, from spatio-temporal integration in the early visual system, to working memory, multisensory integration, object recognition, temporal perception, and control of attention and eye movements. They also include neural mechanisms found throughout the visual system: adaptation, tuned neural responses, topographic maps, and visual evoked potentials. Our speakers explore these links using various cutting-edge behavioral, neuroimaging and computational methods, to position numerical vision in mainstream of vision science.

Spontaneous Perception of Numerosity in Children and Adults

David Burr[1], Giudo Marco Cicchini[2] and Giovanni Anobile[3]
[1]Deparment of Neuroscience, University of Florence, Italy
[2]CNR Institute of Neuroscience, Italy
[3]Fondazione Stella Maris, Italy

Humans and other animals frequently make rapid, nonverbal estimates of numerosity, but it remains controversial whether these are calculated directly or indirectly from density and area. A series of experiments show that provided items are not packed too densely, subjects are far more sensitive to variations in numerosity than in either density or area. In a three-alternative forced choice task requiring discrimination within a space spanning density, area and numerosity, numerosity emerges as the spontaneous dimension. We have extended this line of research with a quick and user-friendly reproduction technique where subjects match by track-pad the size and density of a sample dot-array. Human subjects, including young children and also dyscalculics, show fewer errors along the numerosity direction than in area or density. These experiments show that humans extract number

information, directly and spontaneously, via dedicated mechanisms.

Dynamics of Numerosity Representation in the Early Visual Cortex

Michele Fornaciai and Joonkoo Park
Department of Psychological and Brain Sciences, University of Massachusetts Amherst, MA, USA

Recent studies demonstrated that visual numerosity is represented in low-level visual cortex extremely early in latency. However, whether such representations reflect the perceptual encoding of numerosity or a raw sensory representation of the stimulus remains unknown. Here, we addressed this question using electroencephalogram and functional magnetic resonance imaging, exploiting the connectedness illusion that allows differentiating the raw sensory representation versus perceptual units. Neural activity after 150 milliseconds and in area V3 was biased by perceptual units. In contrast, activity around 100 milliseconds and in area V2 was strictly modulated by sensory units, thus likely reflecting the sensory representation of the stimulus prior to perceptual segmentation. Our findings thus demonstrate that the initial representation of numerosity in early visual cortex is not sufficient for numerosity perception, and that the perceptual encoding of numerosity occurs after segmentation processes later in area V3.

Topographic Quantity Processing Networks in Human Association Cortex

Ben Harvey[1] and Serge Dumoulin[2]
[1]Department of Experimental Psychology, Utrecht University, the Netherlands
[2]Spinoza Centre for Neuroimaging, the Netherlands

Visual perception of numerosity and other quantities is implicated in many perceptual and cognitive functions including foraging, attention control, and decision-making. Numerosity perception shares several properties with perception of (other) simple visual features, and some neurons show numerosity-selective responses. Here, we use 7T functional magnetic resonance imaging and model-based analyses to reveal numerosity-selective neural populations, organized into six widely separated topographic maps in each hemisphere. These numerosity maps are found in regions implicated in object recognition, motion perception, attention control, decision-making, and mathematics. Numerosity tuning properties are very similar between numerosity maps. We also describe networks of distinct but partially overlapping maps responding to other quantities: object size and event duration. As such, these networks link processing of different quantities and suggest roles for quantity processing in many perceptual and cognitive functions.

The Time Course of Individuation and Its Role in Numerical and Visual Cognition

Andreas Wutz and David Melcher
Center for Mind/Brain Sciences, University of Trento, Italy

An abundance of work suggests that numerical cognition is grounded in the visual ability to individuate unique objects (i.e., subitizing). In recent work, we have shown that subitizing is not instantaneous. Instead, it unfolds for at least 100 milliseconds to reach capacity at four items and its time course depends on parieto-occipital alpha oscillations ($\sim$100 milliseconds periodic time). Here, we report novel support for a functional link between individuation and time. First in contrast to subitizing, rapid number estimation (10–30 items) does not depend on time. Second, sustained individuation in a multiple-object tracking task varies in alpha rhythms over time (8–9 Hz). By contrast, average object tracking (its centroid) engaged lower frequencies (4–5 Hz). Together, these results suggest that the core individuation process in visual cognition features a rhythmic profile in the alpha range ($\sim$100 milliseconds) that limits object capacity.

Brain Mechanisms of Arithmetic: A Crucial Role for Ventral Temporal Cortex

Pedro Pinheiro-Chagas[1], Amy Daitch[1], Josef Parvizi[1] and Stanislas Dehaene[2]
[1]Department of Neurology, Stanford University, CA, USA
[2]Department of Experimental Psychology, Collège de France, France

Traditionally, the lateral parietal cortex is considered to host the main hubs for arithmetic processing, while the ventral temporal cortex is thought to play a supportive role in digit recognition. But recent studies suggest that the posterior inferior temporal gyrus (pITG) might play a more high-level role in mental calculation. We tested this hypothesis, by recording electrocorticography signals while subjects solved additional problems. Surprisingly, we found that pITG sites showed an initial burst of activity that parametrically decreased as a function of the magnitude of the operands, yet with a constant integral over the whole trial, making this modulation invisible to slow

functional magnetic resonance imaging. While parietal sites appear to have a sustained function in arithmetic computations, the pITG may be involved in the early identification of the problem difficulty. Overall, our results suggest that the ventral stream contains neuronal populations crucially engaged in mathematical reasoning.

Wednesday, August 29 – Oral presentations

Perception and Action I

Weber's Law in 2D Grasping

Tzvi Ganel[1], Aviad Ozana[1] and Daniel Algom[2]
[1]Department of Psychology, Ben-Gurion University of the Negev, Israel
[2]Department of Psychology, Tel-Aviv University, Israel

The trajectories of grasping movements directed to three-dimensional (3D) objects violate Weber's Law, a fundamental principle of perception. Such violation indicates analytical processing of size. Recent findings suggest that, unlike as in 3D grasping, grasping movements directed to 2D virtual objects adhere to Weber's Law. A possible reason is that typical interactions with virtual objects do not involve grasping movements, which could allow perceptual information to intrude into such actions. In a series of experiments, we explored whether typical interactions with virtual objects on touchscreens could enable analytical processing of size. The results showed otherwise. Movement trajectories obeyed Weber's Law, with linear correspondence between just noticeable differences (JNDs) and object size. Weber's Law was obeyed even following extensive training. The results indicate that active interactions with virtual objects are not performed in a typical, analytical manner.

Grasping in Depth Shows the Same Biases as Depth Perception

Karl Kopiske[1], Chiara Bozzacchi[2], Robert Volcic[3] and Fulvio Domini[4]
[1]Cognitive Systems Lab, Chemnitz University of Technology, Germany
[2]Social Brain Lab, The Netherlands Institute for Neuroscience, the Netherlands
[3]Department of Psychology, New York University Abu Dhabi, UAE
[4]Department of Cognitive, Linguistic and Psychological Sciences, Brown University, RI, USA

How we pick up an object depends critically on its size and its egocentric distance. However, it has been shown that when depth is defined by binocular cues only, perceived distance and depth are systematically overestimated close to the observer but underestimated when further away, with corresponding biases in grasping. Recently, however, it has been proposed that under certain conditions, the motor system can compute a veridical depth estimate when perception cannot. We present three experiments showing distance effects in grasping along the depth axis and consistent distance effects on depth estimates. These biases were obtained even in the presence of additional depth cues given through viewing an object from above and a ground plane. Availability of online visual feedback during grasps reduced the distance effect, but only when the object was viewed from above. This shows that across a wide range of conditions, grasping in depth is subject to the same biases as depth perception.

Grasping the Uznadze Illusion: Hand Shaping Is Driven by Relative Size As Well As Stimulus Similarity

Stefano Uccelli, Veronica Pisu, Lucia Riggio, Gioacchino Garofalo and Nicola Bruno
Dipartimento di Medicina e Chirurgia, Università degli studi di Parma, Italy

In the Uznadze illusion, physically identical targets appear smaller when preceded by larger stimuli and larger when preceded by smaller stimuli. However, this perceptual effect decreases when the involved stimulus pairs are dissimilar (in shape, orientation, or color). Does stimulus pair similarity affect the Uznadze illusion on the motor system? We asked participants to grasp or manually estimate a target disk preceded by a smaller, identical in size, or larger inducer. In the first condition, we used congruent stimuli; in the second condition, we manipulated similarity using inducers with different shape and lightness. We recorded grip aperture in an open-loop procedure. Results show strong and comparable illusory effects in both the perceptual and the motor task in the congruent condition and a decrease of effects in both tasks with incongruent stimuli. Our results suggest that, at least in these conditions, perception and action are similarly affected by contextual information.

Uncertainty in Coordinate Transformations Affects Obstacle Avoidance

Parisa Abedi Khoozani[1], Dimitris Voudouris[2], Gunnar Blohm[1] and Katja Fiehler[2]
[1]Center for Neuroscience, Queen's University, Canada

[2]Department of Psychology and Sport Sciences, Justus-Liebig University Giessen, Germany

Humans can perfectly reach an object without colliding with other objects; obstacle avoidance. Often, we perform such reaching movements in different postures, that is, sitting or lying. Varying postures lead to higher uncertainty in perception and consequently higher variability in action. However, it is unknown if this higher variability, due to stochastic reference frame transformations (RFTs), extends to obstacle avoidance. Participants were asked to reach with a two-dimensional robot manipulandum toward a visual target, 20 cm away, while avoiding an obstacle. The obstacle was positioned midway between start and target position with random shifts (0, 2, and 4 cm) to right/left. In order to vary sensorimotor variability, reaching movements were performed in three head roll postures: 0° and 30° to the right or left. We observed larger error margins for rolled compared to upright head postures. This result demonstrates that humans consider higher variability added by stochastic RFTs while avoiding obstacles.

How Do We Deal With Accelerating Objects Despite Our Visual System's Dismal Ability to Judge Acceleration?

Eli Brenner, Cristina de la Malla, Patricia García Delgado and Jeroen B. J. Smeets
Department of Human Movement Sciences, Vrije Universiteit Amsterdam, the Netherlands

To answer this question, we asked participants to tap on targets that either accelerated or decelerated while moving to the left or right at different speeds. When all the options were randomly interleaved, participants hit ahead of decelerating targets and behind accelerating targets. These biases disappeared when several consecutive targets either all accelerated or all decelerated. Participants gradually aimed further or less far ahead of the target. The biases also disappeared within about 10 trials when accelerating targets moving to the left were interleaved with decelerating targets moving to the right, presumably because participants learnt to aim further to the left. With the opposite pairing of direction and acceleration they presumably learnt to aim further to the right. Such learning based on recent errors explains how people can deal with recurrent acceleration due to friction or gravity despite their poor perception of acceleration.

A Single Response Mechanism Accounts for Spatial and Temporal Responses in a Timing Task

Joan Lopez-Moliner[1], Elisabet Tubau[1] and David Aguilar-Lleyda[2]
[1]Institut de Neurociencies, Universitat de Barcelona, Spain
[2]CNRS & Paris 1, Centre d'Économie de la Sorbonne, Paris

Many tasks require that we synchronize our actions with particular moments along the path of moving targets. However, it is still controversial whether we base these actions on spatial or temporal information. We measured response times in a coincidence timing task: Participants had to press a key to prevent a target from crossing a line. Our design increased reward for actions, the closer (in space or time) these were made to the line, but penalizing after-line actions. We used three motion durations and three speeds and impaired motion processing in one condition. Results showed larger reward for invariant responses in time (rather than space) across speeds, and this pattern was promoted by longer motion durations. We modeled positional and speed uncertainty with a Kalman filter in which speed uncertainty depended on motion duration. A single spatial mechanism could account for both spatial and temporal patterns across all conditions, providing a unified computational explanation.

Perception and Action II

Never Alone: Group Belongingness as a Determinant of the Emotional Semantic Congruency Effect

Giulio Baldassi, Sara Rigutti, Marta Stragà, Tiziano Agostini, Andrea Carnaghi and Carlo Fantoni
Department of Life Sciences, University of Trieste, Italy

In previous experiments, we found that the speed of motor responses in emotion comparisons was mirrored by emotion intensity. Responses were faster and more accurate with emotional rather than neutral faces: a novel Emotional Semantic Congruency effect, ESC. In four experiments, we tested how ESC is molded by the social context. Participants performed our emotion comparison task individually though concurrently in groups of eight. Experiments differed in term of presence/absence of group's categorization (minimal group paradigm), and presence/absence of inter-/intra-groups competition (individual/cumulative scoring). Categorization and Competition jointly affects two components of emotion comparison both probes of mood state: Response speeds (arousal) were equally affected by Categorization and

Competition, while Categorization per se enhanced a happiness advantage involved in our task (valence). Group belongingness, not loneliness, enhances the quality of global experience.

The Neural Correlates of Adult and Infant Action Syntax

Laura Maffongelli[1], Alessandro D'Ausilio[2], Luciano Fadiga[2] and Moritz M. Daum[3]
[1]Department of Psychology, Scene Grammar Lab, Goethe Universität Frankfurt, Germany
[2]Section of Human Physiology, University of Ferrara, Italy
[3]Department of Psychology, University of Zurich, Switzerland

Language sentences and goal-directed actions are composed of sub-elements chained together according to specific rules to build up a meaning over the temporal course. Therefore, predicting upcoming events in an action sequence can be compared to the way we process language information. Goal-directed actions can be sequenced in small units (movements/motor acts), which are organized according to a hierarchical plan, resembling the hierarchical organization of language. Two event-related potentials studies conducted with adults and infants addressed whether a syntax hub exists also in the action domain. Results suggest that manipulating the syntax of observed goal-directed actions leads to cortical signatures analogous to those activated by similar manipulations of sentence syntax. Both studies support the hypothesis that some basic mechanisms, such as the rule-based structuring of sequential events, starting early in development, are shared between different cognitive domains.

Neural Tracking of Self and Other During Joint Movement Synchronization

Manuel Varlet, Sylvie Nozaradan, Patti Nijhuis and Peter E. Keller
The MARCS Institute for Brain, Behaviour and Development, Western Sydney University, Australia

Humans coordinate their movements to perform everyday tasks together. Optimal joint performance requires individuals to continuously anticipate and adapt to spatial and temporal characteristics of each other's movements. Here, we investigate with dual electroencephalogram (EEG) and frequency tagging techniques the neural tracking of self- and other-generated movements during a joint visuomotor improvisation task. We examined neural responses to self and other movement in dyads producing synchronized horizontal forearm movements when leader–follower relation was manipulated. The results indicated that participants exhibited large EEG responses to other-produced movement but also to their own movement and that the amplitude of those responses was modulated depending on leader–follower constraints. A positive correlation between the amplitude of EEG responses and interpersonal movement synchronization was also found, opening new perspectives to understand perceptual-motor mechanisms underlying joint action.

A Common Cause for the Phenomenological and Sensorimotor Correlates of Limb Ownership

Cesare Parise[1], Majed Samad[1], Sean Keller[1] and Massimiliano Di Luca[2]
[1]Research Department, Oculus, CA, USA
[2]School of Psychology, University of Birmingham, UK

The feeling that our limbs belong to our body is a central aspect of the bodily self, known as the sense of ownership. Recent studies questioned whether two traditional ways of assessing ownership (phenomenological questionnaires and proprioceptive drift) reflect a single underlying mechanism. We used state-of-the-art hand-tracking technology in virtual reality and parametrically varied spatial and temporal offsets between real and virtual hand. After brief experience with the virtual hands, participants performed an unseen reaching task aimed at assessing perceived hand location and filled a questionnaire about their experience. We found that across conditions, the phenomenological feeling of ownership strongly correlated with perceived hand location. Using a Bayesian model that makes a causal inference about the visual and proprioceptive hand, we show that all correlates of limb ownership are driven by a general purpose mechanism for multisensory integration.

Action-Based Predictions Lead to Reduced Neural Processing of Visual Stimuli Regardless of Temporal Predictability

Bianca van Kemenade, Christina Lubinus, Tilo Kircher and Benjamin Straube
Department of Psychiatry and Psychotherapy, Philipps-University Marburg, Germany

Sensory consequences of one's own action are often perceived as less intense and lead to reduced neural responses, compared to externally generated stimuli. Here, we investigated whether this phenomenon is due to the efference copy or differences in temporal predictability. During functional magnetic resonance imaging data acquisition, participants had to judge which one of two

visual stimuli was brighter. In predictable blocks, the stimuli appeared temporally aligned with their button press (active) or aligned with an automatically generated cue (passive). In unpredictable blocks, stimuli were presented with a variable delay after button press/cue, respectively. Self-generated stimuli were perceived as darker and led to less neural activation in visual areas than their passive counterparts, indicating sensory attenuation for self-generated stimuli. An effect of temporal predictability was not found. Therefore, our results suggest that sensory attenuation is mainly driven by action-based predictive mechanisms.

Sight Restoration in Congenitally Blind Individuals: Visuo-Motor Adaptation

Irene Senna, Sophia Pfister and Marc O. Ernst
Department of Applied Cognitive Psychology, Ulm University, Germany

In our daily life, we easily integrate vision with other sensory signals (e.g., proprioception) to plan and guide actions. When a systematic error is introduced, for instance by prism goggles shifting a target's apparent location, we can still reach for the target by recalibrating the sensory-motor system (SMS). In the present study, we investigated whether newly sighted patients (born with bilateral cataract, and surgically treated after years of visual deprivation) are able to recalibrate the SMS, minimizing the error. Unlike sighted controls, patients only slightly reduced the error, without fully adapting to the visual shift. Such finding cannot be explained only by low vision: Blurring vision in controls did not impair their ability to adapt to the visual shift and patients' ability to reduce the error correlated with time since surgery. Visuo-motor recalibration is not present immediately after surgery, but it seems to require time (and thus sensory-motor experience) to develop.

Lightness and Brightness & Surface and Texture

Integrating Color, Contours, Shading, and Texture: When Does Covariation Matter?

Steven Zucker[1] and Benjamin Kunsberg[2]
[1]Department of Computer Science, Yale University, CT, USA
[2]Department of Applied Mathematics, Brown University, RI, USA

There are many cues to shape (e.g., contours, shading, and texture) and to material (texture and color). They overlap: sometimes cooperating (texture and shading on cement ball) and sometimes competing (ripening fruit). Misinterpreting ripening as shading forces incorrect shape inferences; discounting a relevant source misses useful information. How can our brains resolve cue interaction while, concurrently, inferring shape? Our answer is in the different oriented patterns that arise in visual cortex. When hue flows with intensity – the oriented gradient patterns are parallel – the effect is perceived as material and shapes appear flatter. We identify salient regions in which shading approaches (limiting) "critical contours" that partition the surface into meaningful parts. Shapes appear flatter when the hue flow is parallel only near critical contours, regardless of color elsewhere. Not all locations are equally important.

A Role for Metallicity in the Perception of Surface Reflectance

Matteo Toscani[1], Dar'ya Guarnera[2], Giuseppe Claudio Guarnera[2], Jon Yngve Hardeberg[2] and Karl Gegenfurtner[1]
[1]Department of General Psychology, Justus-Liebig-Universität Gießen, Germany
[2]Department of Computer Science, Norwegian University of Science and Technology, Norway

The bidirectional reflectance distribution function (BRDF) describes the reflectance properties of a surface. Prior work suggests that BRDFs reduce to two perceptual dimensions: lightness and gloss. We investigated the dimensionality of BRDFs of a wider range of materials than in prior work (a 64 materials dataset, rendered with a more realistic reflectance representation). Participants repeatedly ranked four rendered three-dimensional shapes according to their surfaces' similarity to a reference shape; materials were randomly sampled from the dataset. We used multidimensional scaling (MDS) to assign a metrical embedding to our set of stimuli. At least three dimensions are required to explain more than 80% of the embedding's variance. Additionally, participants rated stimuli according to 30 adjectives. Principal component analysis on the ratings suggests that the first three components mostly refer to gloss, albedo and metallicity. These dimensions highly correlated with the first three dimensions of the MDS embedding.

The Pupillary Light Response Reflects High-Priority Content in Visual Working Memory

Cecilia Husta[1] and Sebastiaan Mathôt[2]
[1]Department of Science and Engineering, University of Groningen, the Netherlands
[2]Department of Experimental Psychology, University of Groningen, the Netherlands

Pupil size changes not only in response to objective brightness, but also in response to covert shifts of attention toward bright or dark objects. This led to the question whether internal shifts of attention within representations stored in visual working memory lead to similar effects. Thirty participants encoded the brightness of a black and a white circle and retained one of the two stimuli, indicated by a cue that was presented either before (procue) or after (retrocue) the stimuli. The procue allowed participants to covertly attend to either the bright or the dark stimulus, which affected pupil size, as reported in previous studies. But crucially, even though the retrocue was presented after the stimuli had been removed from the display, the resulting internal shift of attention toward the bright or dark stimulus still affected pupil size. Our findings show that shifting attention, even within the visual working memory representation, affects the pupillary light response.

Changes in Relative Area Produce Equal and Opposite Effects on Lightness and Perceived Illumination

Alessandro Soranzo[1] and Alan Gilchrist[2]
[1]Department of Psychology, Sheffield Hallam University, UK
[2]Psychology Department, Rutgers University, NJ, USA

In prior work in which subjects looked into two windows in the far wall of a vision tunnel and adjusted the level of illumination in one window to match that of the other, they matched the windows for highest luminance (not average). The fact that both lightness and perceived illumination are anchored by highest luminance directly implies Koffka's invariance theorem. For a given luminance within a framework, changing highest luminance changes lightness and perceived illumination in equal but opposite ways. In this new study, we consider area effects. We found that when a darker region is less than half of the total area within a window, Koffka's theorem applies directly. However, when the darker region covers more than half of total area, Koffka's principle applies to the darker region, but not the lighter one, which is anchored at white. Perceived illumination level can now be incorporated systematically into anchoring theory.

The Contribution of the Pictorial Cues Underlying the Adelson Illusion

Paul George Lovell and Kenneth Scott-Brown
Department of Social and Health Sciences, Abertay University, UK

The Adelson illusion (featuring a block made of four cubes) shows the difference between lightness and brightness. Two surfaces share the same RGB value (brightness), yet their appearance (lightness) differs. The directly illuminated surface appears darker than the shadowed surface. This is because the brain is concerned with materials, and the effects of lighting are discounted. We rendered a scene and ensured a match between the pixel values of the two surfaces. The pictorial elements in the scene are isolated (shadow, edges, neighbouring tile colours for the top, leftside and right-side, and the target tile shapes). Participants were presented with versions of the Adelson stimulus using combinations of the elements and were asked to rate the relative lightness of the top and side surface using a 9-point Likert-type scale. A regression analysis confirmed that the co-planar neighbouring tiles (leftside, top) most strongly influenced the switch from judgements of brightness to lightness.

Edge Integration Theory Explains the Lightness of Real Surfaces Viewed Under Gelb Illumination

Michael Rudd
Department of Physiology and Biophysics, University of Washington, WA, USA

Edge integration theory (EIT) has previously been applied mainly to explain the lightness of simple artificial stimuli such as 2D Mondrians or computer-generated disk-annulus displays. Here, I show that EIT can also explain the lightness of real surfaces viewed under Gelb illumination. I show how the theory gives a unified account of: (a) the different lightness scaling of papers in a staircase-Gelb display depending on whether the papers are presented against a dark background or surrounded by a white border (data from Cataliotti and Gilchrist); (b) increases in the lightness and SLC magnitude of targets in a classical simultaneous contrast display as illumination is increased (data from Daneyko and Zavagno); (c) the lightness dissimilarity judgments of Logvinenko and Maloney. In each case, the theory assumes that the luminance step at the sharp outer edge of the illumination framework is spatially integrated with the target reflectance edge to determine target lightness.

Faces

How Discriminable Are Visually Expressed Attitudes?

Chris Davis and Jeesun Kim
The MARCS Institute, Western Sydney University, Australia

Talkers can express different attitudes by changing how an utterance is said rather than by what is said. Most studies

have investigated these prosodic changes by measuring vocal properties; we investigated this by measuring changes in visual ones (Facial Action Units and head motion). Using linear discriminant analyses (LDA) and a recognition experiment, we determined the extent to which different attitudes can be discriminated. Data were collected from three talkers expressing six intentional attitudes, "warning," "criticism," "doubt," "suggestion," "longing," "neutral" for four within-session trials across four different day sessions. Face/head motion was tracked using a Constrained Local Neural Field model on two-dimensional (2D) movies (confirmed using 3D tracking). Within-talker productions were more consistent, both within and across sessions. LDA and the experiment showed that attitudes were discriminable; with some better recognized than others and some talkers much clearer than others.

Orientation Sensitivity at Different Levels of Face Processing

Christianne Jacobs, Charlotte Raskopf, Vincent Malotaux, Kirsten Petras and Valerie Goffaux
Research Institute for Psychological Science, UC Louvain, Belgium

For natural scenes, orientation sensitivity is lowest for horizontal image content, supposedly because of its low diagnostic value. In contrast, for human face identification, the information captured in the horizontal range is most relevant. We investigated whether this functional benefit of horizontal tuning for high-level identity processing is rooted in a low-level horizontal preference as measured with an orientation detection task performed on face images. As expected, face identification performance was highest for horizontally filtered images compared to vertical and oblique orientations. But the pattern reversed completely for the low-level task, which showed reduced orientation sensitivity to horizontal orientations as compared to oblique and, to a lesser extent, vertical orientations. This result indicates that although horizontal information is attenuated at low-level stages of face processing, it nonetheless undergoes privileged processing at high levels.

Fixed or Flexible? Orientation Preference in Identity and Gaze Processing in Humans

Valerie Goffaux and Maria Vasilopoulou
Psychological Sciences Research Institute (IPSY), UC Louvain, Belgium

The human face is a horizontally structured stimulus, and the processing of identity is tuned to this orientation range. In contrast, gaze shifts are mostly represented in the vertical range. We investigated whether the face processing system flexibly tunes to vertical information when processing gaze direction, or whether it invariantly relies on the horizontal range, supporting the domain specificity of face processing orientation tuning and the gateway role of H face information. We found that most participants identified faces better based on horizontal than vertical information confirming the horizontal tuning of face identification. These individuals revealed on average a V-tuned sensitivity to gaze direction. The vertically tuned processing of averted gaze favours the hypothesis that the visual encoding of face information flexibly switches to the orientation channel carrying the cues most relevant to the task at hand.

The Sampling Rate of Face Processing as Measured by the Face Distortion Illusion

David Melcher[1], Giacomo Aldegheri[2] and Chad Dubé[3]
[1]CIMeC, University of Trento, Italy
[2]Donders Institute for Brain, Cognition, and Behaviour, Radboud University, the Netherlands
[3]Department of Psychology, University of South Florida, FL, USA

Humans have an impressive capacity to quickly distinguish and recognize individual faces. Face perception has typically involved studies in which a single face appears, followed by a response. In natural viewing, however, we make three to five saccadic eye movements per second, changing the retinal image with each glance, raising the question of whether there is a "frame rate" for the face processing system. We investigated the sampling frequency of face perception using the "face distortion" illusion, in which viewing a sequence of normal face images aligned at the eyes results in subjective experience of grotesque/distorted faces. We varied presentation rate between 1 and 12 Hz. The illusion was optimal for frequencies of around 3 Hz and largely disappeared at higher presentation rates. These findings are consistent with the theory that meaningful perception of objects and events involves temporal sampling in the theta frequency.

Adaptation to Other People's Eye Gaze Reflects Habituation of High-Level Perceptual Representations

Colin Palmer and Colin Clifford
School of Psychology, UNSW Sydney, Australia

Our sense of where another person is looking depends upon multiple features of their face, relating to both the deviation of their irises and the angle of their head. In this way, gaze direction is a higher level perceptual property that is abstracted from lower level cues. Here, we test whether adaptation to gaze direction acts on higher level representations or lower level features of the face alone. Participants were adapted on faces that evoke the Wollaston illusion, in which the direction that the face appears to look differs from its veridical eye direction. The changes in perception following adaptation were consistent with habituation to the perceived gaze direction of the Wollaston faces, where this is dependent on integration of eye and head direction, rather than to lower level sensory features of the face alone. This constitutes strong evidence for adaptable representations of other's gaze direction in the visual system, which are abstracted from lower level facial cues.

Eye Gaze and Pointing Gestures Are Precise Social Cues

Ailbhe McKinney, James Gillen and Nuala Brady
School of Psychology, University College Dublin, Ireland

Triadic eye-gaze is a powerful social cue that signals where a person is attending and what they are interested in, and our visual acuity for discerning gaze direction is excellent. But what about the pointing gesture? In our first experiment, comparing acuity for these cues, 21 participants judged the direction of where a live model was pointing (left and right hand) or gazing (with her arms by her side) over an interpersonal distance of 2 m. Results indicate comparable best performance thresholds for pointing and gaze perception of between 0.5° and 0.7° of visual angle. In a second study, we compare acuity for these cues at central and at more peripheral regions of the observers' visual field. Our findings reveal that we are very precise in perceiving the direction of another individual's line of regard, for pointing and eye gaze alike, a result that echoes the linked development of these perceptual skills in infancy and their role in initiating joint attention.

Clinical

Action Blindsight and Antipointing in a Hemianopic Patient

Edward de Haan[1], H. Steven Scholte[1], Anouk Smits[1], Noor Seijdel[1] and Robert Kentridge[2]
[1]Department of Psychology, University of Amsterdam, the Netherlands
[2]Department of Psychology, University of Durham, UK

Blindsight refers to the observation of residual visual abilities in the hemianopic field of patients without a functional V1. Given the within- and between-subject variability in the phenomenal experience of blindsight patients, the fine-grained description of the phenomenon is still debated. Here, we tested a patient with established 'perceptual' and 'attentional' blindsight. Using a pointing paradigm patient MS, who suffers from a complete left homonymous hemianopia, shows clear above chance manual localisation of 'unseen' targets. In addition, target presentations in his blind field led MS, on occasion, to spontaneous responses towards his sighted field. Thus, visual stimulation of his blind field can lead to 'action blindsight' and spontaneous antipointing. With respect to the latter, we suggest that MS may have registered the stimulation and subsequently presumes it must have been in his intact half field.

Resting-State fMRI Reveals Functional Networks That Correlate With Visual Training Effects in Chronic Hemianopia

Hinke Halbertsma[1], Joris A. Elshout[2], Douwe Bergsma[2], Frans W. Cornelissen[1], Koen V. Haak[2] and Albert V. van den Berg[2]
[1]Department of Ophthalmology, University Medical Centre Groningen, the Netherlands
[2]Donders Institute of Brain, Cognition and Behaviour, Radboud University, the Netherlands

Visual training can improve the visual field defect of some patients with chronic hemianopia. However, not all patients benefit to the same extent, not even those with similar defects. Here, we investigate whether resting-state (RS) brain activity may predict training outcome. Based on RS functional magnetic resonance imaging (fMRI) data obtained prior training, we assessed 10 functional brain networks in 30 participants with hemianopia. Individual RS networks were defined through dual-regression of templates from an independent dataset of healthy individuals. Training effect was quantified in terms of global sensitivity change (dB) of the visual field and the equivalent (V1) cortical surface gain, based on Humphreys and Goldman perimetry, respectively. Using permutation testing, we located

functional clusters whose visual network association correlated with training effect. Our finding suggests that RS fMRI may be able to identify patients with high potential training outcome.

Observation of Intermittent Exotropia Treatment With Dichoptic Visual Training Based on Virtual Reality Platform

Jin Zeng[1], Xue Li[1], Cheng Yang[1], Yan Zhang[1] and Li Yan[2]
[1]Department of Ophthalmology, Guangdong General Hospital, China
[2]National Engineering Research Center for Healthcare Devices, China

To evaluate the effect of dichoptic visual training based on virtual reality platform mounted display in intermittent exotropia patients and to explore the potential usefulness of this option of treatment. A total of 25 intermittent exotropia patients were recruited. Hirschberg Test, prism and alternate cover testing, perceptual eye position and stereopsis were evaluated after 1 month, 3 months, 6 months of visual neuroplasticity training with a computer-controlled perceptual examination evaluation system. After 6 months of perceptual training, a new order stereopsis was established and eye positions were improved in all 25 patients. Perception training can remove obstacles in the visual processing channel and repair the defects in visual function. The clinical manifestations were the degree of strabismus decreased or abolished, and stereopsis established.

Screening for and Reconstructing Visual Field Defects Based on Free-Viewing Eye Movements

Birte Gestefeld[1], Alessandro Grillini[1], Jan-Bernard C. Marsman[2] and Frans W. Cornelissen[1]
[1]Department of Experimental Ophthalmology, University Medical Center Groningen, the Netherlands
[2]Neuroimaging Center, University Medical Center Groningen, the Netherlands

Automated perimetry, currently the gold standard for assessing visual field defects (VFD), requires focusing on a fatiguing task for a long time. Therefore, it can be hard to perform in various patient populations. Assessing free-viewing eye movements may provide a simplified alternative assessment. In the free-viewing test, participants watch short movie clips (1 minute), while their eyes are being tracked. We assessed the feasibility of screening for and reconstructing VFD with healthy participants who performed the test while we simulated different VFDs. We show that machine learning can accurately distinguish between different VFDs based on eye movement features. Moreover, it is also possible to reconstruct the location of relatively small VFDs based on the distribution of fixations and viewing priority. We conclude that free-viewing eye movements provide a viable alternative to screen for VFDs in clinical populations that may otherwise remain unassessed.

Visual Plasticity in Retinitis Pigmentosa

Claudia Lunghi[1], Lucia Galli Resta[2], Paola Binda[3], Guido Marco Cicchini[2], Giorgio Placidi[4], Benedetto Falsini[4] and Maria Concetta Morrone[3]
[1]Laboratoire des systèmes perceptifs, Département d'études cognitives, Ecole Normale Superieure & CNRS, Paris
[2]Institute of Neuroscience, National Research Council (CNR), Italy
[3]Department of Translational Research and New Technologies in Medicine and Surgery, University of Pisa, Italy
[4]Department of Ophthalmology, Policlinico Gemelli, Università Cattolica del Sacro Cuore, Rome

Retinitis pigmentosa (RP) is a genetic disease that induces progressive retinal degeneration. Therapeutic strategies for RP are aimed at restoring or substituting retinal input. However, it is unclear whether the visual cortex of RP patients retains plasticity to react to the restored visual input. To investigate this, we tested the effect of short-term (2 hours) monocular deprivation on ocular dominance (OD, measured with binocular rivalry) in a group of 14 patients diagnosed with RP (visual field sparing of 10°). After deprivation, RP patients showed a perceptual shift in OD in favor of the deprived eye ($p = .001$), reflecting visual plasticity comparable to normal sighted subjects. The deprivation effect negatively correlated both with visual acuity ($r = -.57$, $p = .03$), and fERG amplitude ($r = -.66$, $p = .02$), revealing a progression of visual cortical plasticity in RP. Our paradigm might provide a new tool to assess patients' ability to adapt to altered visual inputs and benefit of prospective therapies.

Priors for the Detection of Socially Meaningful Stimuli as Perceptual Markers for Psychosis Proneness

Philipp Sterzer, Heiner Stuke, Elisabeth Kress, Veith Andreas Weilnhammer and Katharina Schmack
Department of Psychiatry, Charité Universitätsmedizin Berlin, Germany

Predictive coding accounts of psychosis state that an overweighing of priors relative to sensory information leads to the misperception of meaningful signals, giving rise to the experience of hallucinations and delusions. Here, we hypothesized that such overweighing of priors represents a pervasive alteration that also affects the visual modality. We studied visual perception of socially meaningful stimuli in healthy subjects with varying degrees of psychosis proneness. In two behavioral experiments, we quantified (a) the prior for detecting faces in visual noise and (b) the prior for detecting direct gaze stimuli rendered invisible by continuous flash suppression. We found that the strength of both these priors correlated positively with hallucination and delusion proneness. Our results provide evidence for the idea that overly strong high-level priors for the detection of socially meaningful stimuli might constitute a generic processing alteration in psychosis.

Clinical and Development

Noisier but Still Flexible: Typical Numerosity Adaptation Despite Selectively Impaired Number Acuity in Dyscalculia

Giovanni Anobile[1], Filippo Gasperini[1], Guido Marco Cicchini[2] and David Burr[3]
[1]Department of Developmental Neuroscience, Stella Maris Scientific Institute, Italy
[2]Institute of Neuroscience, CNR, Italy
[3]Department of Neuroscience, Psychology, Pharmacology and Child Health, University of Florence, Italy

Recent theories suggest that a core deficit in the "number sense" underlies dyscalculia. We test this idea by measuring perceptual adaptation and discrimination thresholds to numerosity and to object size in a group of dyscalculic (DD) and math-typical preadolescents. Confirming previous studies, we found that DD participants have higher thresholds for numerosity discrimination, while those for object size were similar to controls. However, dyscalculics adapted to numerosity in a similar way to the typical. This suggests that although numerosity thresholds are selectively higher for dyscalculics, the mechanisms for perceiving numerosity are otherwise similar: perhaps with higher noise levels. This contrasts neatly with recent work showing that autistic perception is associated with reduced adaptation, with no measurable increase in thresholds. These results question the tight link that has been asserted between the number sense and formal mathematical skills.

Synesthesia and Autism Spectrum Disorder: Shared Characteristics of Visual Perception

Tessa M. van Leeuwen[1], Floor Burghoorn[2] and Rob van Lier[1]
[1]Donders Institute for Brain, Cognition and Behaviour, Radboud University, the Netherlands
[2]Faculty of Social Sciences, Radboud University, the Netherlands

Synesthesia is a mixing of the senses, for example, letters elicit colour. Approximately 20% of people with autism spectrum disorder (ASD) have synesthesia; the reason for this high co-occurrence is unclear. We investigated whether perceptual characteristics of synesthetes resemble those reported for ASD and assessed autistic traits in 64 synesthetes and 42 controls. Synesthetes revealed stronger autistic traits on subscales of the Autism Quotient and reported increased sensory sensitivity (Glasgow Sensory Questionnaire). As in ASD, motion coherence thresholds of synesthetes were elevated ($p = .001$), and correlated with sensory sensitivity ($r = .493$, $p = .001$). Similar to reports of enhanced detail processing in ASD, synesthetes made less errors than controls on an Embedded Figures Task ($p = .05$). The results point to a bias towards detail processing in synesthetes, which is also typical of visual perception in ASD. We conclude that atypical sensory processing is a shared feature of synesthesia and ASD.

Atypical Basic Psychophysics in Autism: Violation of Weber's Law in Vision and Haptic

Bat-Sheva Hadad
Department of Special Education, University of Haifa, Israel

We show that the widely documented modulated context effects in autism reach deeper than hitherto suspected, with reduced inference in stimulus encoding, during which the system continuously updates a generative model of the sensory inputs it receives. Specifically, we tested the adherence of vision and haptics to Weber's law, according to which sensitivity to stimulus intensity changes based on a rule of $dI/I = C$, where dI is the increase in intensity to a stimulus I that is required to produce a detectable change. Results for TD confirmed Weber's law, demonstrating a proportional increase in just noticeable differences (JNDs) with intensity, resulting in constant fractions (dI/I) across intensities. The results in autism spectrum disorder, in contrast, showed no scaling of JNDs with intensity; instead, fractions decreased linearly with intensity. In contrast to its consistency in typical perception, Weber's law does not hold in autism. This may account for the atypical perception and for sensory symptoms of autism.

Poor Global Motion Coherence Sensitivity and Attention Deficits in Children With Perinatal Brain Injury, Preterm Birth or Developmental Coordination Disorder: Common Dorsal Stream Deficits?

Janette Atkinson[1], Fleur Corbett[1], Elisa Fazzi[2], Serena Micheletti[2], Daniela Ricci[3], Giorgia Coratti[3], Morag Andrew[4], Peter Sullivan[4], Christine Montague-Johnson[4] and Oliver Braddick[5]
[1]Faculty of Brain Sciences, University College London, UK
[2]Unit of Child Neurology & Psychiatry, ASST Spedali Civili, Brescia, Italy
[3]Pediatric Neurology Unit, Catholic University, Rome
[4]Department of Paediatrics, University of Oxford, UK
[5]Department of Experimental Psychology, University of Oxford, UK

Dorsal stream vulnerability may underpin deficits in motion coherence sensitivity, planned actions and visual attention in many developmental disorders. Participants were 181 'at-risk' (AR) children with perinatal brain injury or very preterm birth, and 65 with developmental coordination disorder (DCD). On the 'Ball in the Grass' test, motion thresholds were higher than form in AR and DCD. On Early Child Attention Battery (ECAB), attention deficits in AR were greater than predicted from IQ, greatest in sustained attention. Individual motion thresholds were correlated with ECAB in AR; form and motion with visuomotor skills in DCD. Results are related to functional magnetic resonance imaging findings that motion coherence sensitivity is correlated with differential brain growth in parietal areas and FA of superior longitudinal fasciculus, visuomotor integration and early mathematics and possible parallels to Duncan's Multiple Demand network.

The Development of Visuo-Haptic Exploration Strategies in School-Aged Children

Alessandra Sciutti[1], Clara Melchiori[2], Giada Lombardi[2] and Giulio Sandini[1]
[1]Robotics, Brain and Cognitive Sciences Unit, Italian Institute of Technology, Italy
[2]Dipartimento di Informatica, Bioingegneria, Robotica e Ingegneria dei Sistemi, Università di Genova, Italy

Since infancy, we explore novel objects to infer their shape. However, how exploration strategies are planned to combine different sensory inputs is still an open question. At ECVP 2017, we showed how adults' exploratory strategies are influenced by the sensory modalities available and by the possibility to move the object. Here, we focus on the development of visuo-haptic exploration, by analyzing how school-aged children explore iCube, a sensorized cube measuring its orientation in space and contacts location. Participants' task was to find specific cube faces while they could either only touch the static cube (tactile), move and touch it (haptic) or move, touch, and look at it (visuo-haptic). Visuo-haptic performances were adult like at 7 years of age, whereas haptic exploration was not as effective until 9 years. These findings are discussed in relation to the development of visuo-haptic integration and in the perspective of enabling early anomalies detection in explorative behaviors.

"Stuck on the Duck"—Gradual Morphing Presentation Slows Down Perceptual Decision-Making in Preschoolers

Elisabeth Stöttinger and Beate Priewasser
Department of Psychology, University of Salzburg, Austria

We use a gradually morphing picture task to measure how people change their mental representation in a slowly changing environment (e.g., when a duck slowly turns into a rabbit). We repeatedly demonstrated that participants see the second object earlier (e.g., when it is still 70% duck) when pictures are presented in a gradually morphing context—most likely reflecting active exploration strategies (e. g., I know it is a duck but what else might it be?). This benefit is reversed after damage to the right side of the brain (RBD): Patients becoming "stuck" on their initial interpretation while performing perfectly normal when the same pictures are presented individually—outside of the morphing context. In this study, we show that performance of healthy children (3–6 years) mirrors performance of RBD patients. We evaluate whether this effect can be explained by verbal IQ, set shifting abilities, or the ability to understand and attribute mental states (Theory of Mind).

Perceptual Organization and Spatial Vision

Coarse Image Information Guides Integration of Fine Details (if You Let It)

Kirsten Petras[1], Christianne Jacobs[1], Sanne ten Oever[2] and Valerie Goffaux[1]
[1]Research Institute for Psychological Science, UC Louvain, Belgium
[2]Department of Psychology and Neuroscience, Maastricht University, the Netherlands

Visual input is broadband by nature and coarse-to-fine theories of vision propose that coarse, low spatial frequency

(SF) information guides the integration of finer, high SF details. Previous studies have measured visual responses to selective and narrow SF ranges, prohibiting direct empirical tests of coarse-to-fine predictions. Using multivariate decoding of EEG patterns, we separated the contribution of distinct SF to the visual response to broadband stimuli in the human brain. Participants viewed intact and scrambled images of human and monkey faces that were either broadband or filtered to contain low or high spatial frequencies only. We trained classifiers on patterns evoked by filtered scrambled stimuli and generalized decoding to broadband intact trials. We found reduced high SF dominance for trials in which low SF was informative towards image content, indicating that coarse information guides the processing of fine detail.

Behavioral Oscillations in Global/Local Processing: Global-Alpha Mediates Global Precedence Effect

Ling Liu and Huan Luo
School of Psychological and Cognitive Sciences, Peking University, China

Visual displays always contain hierarchically organized structures such as global/local information. It remains unclear how dissociated oscillatory components for global/local processing are associated with and contribute to the global precedence effect (GPE). To address the issue, we used a high time-resolved psychophysical method to access the fine temporal structure of global/local processing. Our results demonstrate that the global/local behavioral time courses consist of two concurrent temporal components: a slow developing trend that replicates the classical global advantage effect and a new behavioral oscillatory profile: Global-alpha (~10 Hz) and Local-beta (~20 Hz), consistent with the previous neuroimaging studies. Importantly, the stronger the Global-alpha activations, the larger the typical GPE would be. Together, these findings constitute new behavioral evidence advocating the central function of distinct neuronal oscillations in mediating global/local analysis of visual inputs.

Does the Processing of Closure Need the Primary Visual Cortex: A tDCS Study

Weina Zhu[1], Weixiong Li[1] and Jan Drewes[2]
[1]School of Information Science, Yunnan University, China
[2]Institute of Physics, Chemnitz University of Technology, Germany

The discrimination of closure is faster and easier than that of other geometrical features. However, the neural substrate underlying this advantage is yet unclear. We hypothesized that closed figures may be processed via a rapid subcortical shortcut to anterior temporal lobe (ATL), bypassing V1. We tested this by using transcranial direct current stimulation (tDCS) in an odd quadrant task. Subjects received sham/active cathodal-inhibitory tDCS over V1. In the task, all four quadrants each contained a figure and subjects were asked to pick one from the other three. The disparate quadrant differs from the rest either in geometric properties (orientation) or in topological properties (closed/open). After suppressing V1, a decrease of performance was found in the geometric properties but not in topological properties. This suggested that the discrimination of closure does not necessarily depend on the initial processing at V1 and may be mediated via a rapid subcortical pathway to ATL.

Gestalts at Threshold: A Comparison of Basic Emergent Features

Thiago Leiros Costa, Pieter Moors and Johan Wagemans
Brain and Cognition, KU Leuven, Belgium

We start from the proposal that 'not all Gestalts are equal' and use psychometric functions to address the challenges of operational definition and comparison of these phenomena. We tested two-dot stimuli in a change detection task to measure the salience of the emergent features (EFs) of proximity and orientation using the psychophysical method of constant stimuli. The two dots could change in the configural domain (orientation/proximity) or change location without changing configuration (control condition). Two-dot stimuli were used to isolate EFs with minimal confounders. Results show that the slopes of the psychometric functions and the thresholds differed between orientation, proximity and control conditions, suggesting that these EFs rely on different processing mechanisms. Participants were also more sensitive to changes in orientation than proximity. This work demonstrates the feasibility of using classical psychophysics to diagnose and compare Gestalt phenomena.

Detecting Simultaneity Following Late Sight Onset in Congenital Cataract Blinds

Tapan Gandhi[1], Piyush Swami[1], Shefali Gupta[1] and Pawan Sinha[2]
[1]Department of Electrical Engineering, Indian Institute of Technology Delhi, India
[2]Department of Brain and Cognitive Sciences, MIT, Cambridge, MA, USA

The elemental judgment of whether two events happened together in time forms the basis for inferring relationships between them. Past work has shown that windows of simultaneity progressively narrow over the developmental

timeline. To address these issues, we assess simultaneity judgments in visual and auditory paradigms in a set of longitudinal studies with congenitally blind children who were provided sight surgeries as part of Project Prakash (www.ProjectPrakash.org), beginning immediately after sight onset. The preoperative data suggest that the subjects are impaired in accurate judgment of simultaneity but learn this ability in longitudinal time line. By following the Prakash children over extended durations (a few years), we hope to be able to determine whether they are ever able to match the simultaneity windows of their normally sighted counterparts, or if there are potentially permanent differences, pointing to sensitive periods in development for this skill.

Never Repeat the Same Trick Twice – Unless It Is Based on Amodal Completion

Vebjørn Ekroll[1], Evy De Bruyckere[2], Lotte Vanwezemael[2] and Johan Wagemans[2]
[1]Department of Psychosocial Science, University of Bergen, Norway
[2]Laboratory of Experimental Psychology, KU Leuven, Belgium

According to magicians, you should never repeat the same trick. The vanishing cigarette trick investigated by Kuhn and Tatler is a case in point. It is possible, though, that repetition of a magic trick may be very risky for some tricks but almost riskless for other tricks. In particular, one would expect that tricks based on perceptual illusions can be repeated many times with little risk that the spectators are able to figure out the secret. We tested this prediction using four tricks based on amodal completion and four tricks involving attentional misdirection. The participants viewed video clips of the tricks 3 times and were asked to explain what they think the secret behind the trick is after each presentation. We found clear differences between the tricks based on amodal completion and those involving attentional misdirection. The former are more difficult to solve, and the solution rates only increase marginally with repeated exposure.

Colour

A Curious Feature of Thresholds for Discriminating Colorimetric Purity

Marina Danilova[1] and John Mollon[2]
[1]Visual Physiology Laboratory, IP Pavlov Institute of Physiology, Russia
[2]Department of Psychology, Cambridge University, UK

Colorimetric purity increases along any radial line from the white point in chromaticity space. Its subjective correlate is the saturation of the colour. Using a four-alternative, spatial forced choice, we measured purity thresholds along a line such that the only variation was in the ratio of excitation of the long- and middle-wave cones. The foveal targets were brief (120 milliseconds) increments presented on a steady white field that had the chromaticity of Illuminant D65 and a luminance of 10 cd.m^{-2}. The mean luminance of the targets was 10% greater than the field; and additionally, the positive stimulus and the three distractors were independently jittered in luminance by $\pm 1\%$, to avoid detection by luminance cues. As would be expected from the literature, Weber fractions for purity discrimination are smallest near the white point and increase as the reference purity increases, but the function is double branched, in that thresholds increase more slowly at higher purities.

Colour Synthesis

Jan Koenderink[1], Andrea van Doorn[2] and Karl Gegenfurtner[3]
[1]Brain & Cognition, KU Leuven, Belgium
[2]Department of Experimental Psychology, Utrecht University, the Netherlands
[3]Department of Psychology, Giessen University, Germany

We present an investigation of the variability in colour synthesis of RGB (display) colours. Participants synthesised fiducial colours using a colour picker in a setting that emulated the situation encountered in generic applications. From about 3,000 settings of 50 participants, we construct a smooth field of covariance ellipsoids, covering the whole RGB-space. These ellipsoids have a variety of sizes, shapes and orientations, most being predominantly prolate. The variance is about 20 times larger than the conventional just noticeable differences (JNDs), but the ellipsoids correlate quite well with the familiar MacAdam data. We use the data to obtain reasonable estimates of, for instance, the number of colours (colour atlas), hues (colour wheel) or grays (gray scales).

A Model of How Memory Colors Effect Arises in a Recurrent Neural Network

Dražen Domijan and Mateja Marić
Department of Psychology, University of Rijeka, Croatia

When observers adjust the colors of diagnostically colored objects to a subjective grayscale they tend to select a shade of gray that contains a small amount of complement color. For example, gray banana is typically adjusted to a slightly bluish gray. This is known as a memory colors

effect. Here, we showed how this effect is explained by a neurocomputational model of color perception based on an adaptive resonance theory. The effect is attributed to the adaptation or habituation in a feedback pathway from color categories to the color-opponent representation. This adaptation creates small imbalance in synaptic connectivity that bias competition between color categories towards selection of complement color. We conclude that it is possible to observe memory color effect in a computational model designed to achieve stable color categorization.

Color Scission Versus Spatial Integration for Real Lights on Real 3D Objects

Qasim Zaidi and Romain Bachy
Graduate Center for Vision Sciences, State University of New York, NY, USA

Identifying illumination color on a scene helps to judge season and time of day and could function in computations for object color determination. Lights of six different colors were presented over subsets of 64 real matte or glossy objects, and observers matched the illuminant color on real grey level objects matched for albedo. The results were fitted with spatial integration and scission models. Observers estimated the color of solo illuminants by spatially integrating every chromaticity in the scene and thus made systematic errors depending on the distribution of object spectral reflectance. With two spatially contiguous illuminants, however, a scission process enabled almost veridical illuminant color estimation across surface reflectance distributions. The results are surprisingly similar to those for synthetic scenes of flat and matte surfaces, despite the fact that scenes with three-dimensional (3D) objects contain highlights and gradients theoretically sufficient to infer the illumination color.

What Are the Mechanisms Behind Colour Adaptation and Afterimages?

Christoph Witzel and Alexander Nowak
Department of General Psychology, Justus-Liebig-Universitaet, Germany

Adaptation is fundamental to colour constancy and its impressive effects are reflected in colour afterimages. Yet, it is not clear what determines the complementary colours produced by adaptation and seen in afterimages. We measured the precise hue of afterimages for 32 inducing colours spread across colour space, and we compared the hue of the afterimages with predictions based on cone-opponency (DKL space), colour appearance models (CIELUV, CIELAB, Munsell), linguistic colour categories, and with the hues of colours induced by simultaneous contrast. Results show that the hues of afterimages coarsely coincide with opponent colours in perceptual colour spaces (DKL, CIELUV, CIELAB); but none of those spaces predicts the precise hue of afterimages for all inducing colours. Hues of induced colours differed between afterimages and simultaneous contrast, and there were no top-down effects of colour categories. These results raise fundamental questions about the mechanisms behind adaptation.

Luminance Spatial Distribution Plays a Major Role in Color Assimilation

Xim Cerda-Company, Xavier Otazu, Nilai Sallent and C. Alejandro Parraga
Department of Computer Science, Computer Vision Center, Spain

Previous studies on color induction concluded that uniform surrounds tend to induce color contrast and striped surrounds tend to induce color assimilation. In this work, we conducted several psychophysical experiments to measure the contribution of the luminance spatial distribution of chromatically striped stimuli to color assimilation. We used Monnier and Shevell's color induction paradigm, defining five luminance and four chromatic conditions (one of the luminance conditions was "equiluminant"). In the four chromatic conditions, we systematically varied the luminance of all stimuli ingredients: the target, the first inducer, the second inducer, and both inducers. We observed that (a) color induction strongly depends on the luminance differences present in the stimuli, (b) there is also a significant dependence on the chromatic inducers (chromatic condition), and (c) color assimilation is stronger in the s direction of MacLeod-Boynton color space than in the one.

Motion and Biological Motion

How Well Can We Judge Speed Across Different Directions?

Oliver Braddick, Rory Trevelyan-Thomas and Catherine Manning
Department of Experimental Psychology, University of Oxford, UK

Visual speed judgments presumably use signals in direction-selective neurons. Is speed discrimination, therefore best when using neurons tuned to the same direction? There is no published evidence on comparing speed between different directions. In four experiments, participants ($N = 65$) judged which was faster: a random-dot reference stimulus (vertical or oblique speed 6 deg/s) versus a comparison stimulus in the same direction or differing by 180°, 45°, or 90°. Weber fractions for

comparisons in the same direction were generally ~20% smaller than for different directions. In contrast to past reports, we found an oblique effect, with finer speed discrimination for vertical compared to oblique motions. We conclude that specific information can be used to compare speed in a common direction, but this supplements a more general process comparing speed representations across directions. This is an example of a wider question: How do observers compare signals in different neural population.

Current Visual Information and Newtonian Prediction is Utilised in the Perception of Colliding Objects

Abdul Deeb, Evan Cesanek and Fulvio Domini
Department of Cognitive, Linguistic, and Psychological Sciences, Brown University, RI, USA

The aim of this study was to determine whether the perception of a collision event is achieved through currently available information or a predictive strategy. Participants viewed billiard collisions in virtual reality, where the cue ball could strike the target on the left, right, or middle. Participants then indicated the resulting trajectory of the target. When both balls disappeared upon collision, trajectory judgments were consistent with Newtonian mechanics. In other trials, participants viewed 40 or 80 milliseconds of target ball motion (independent of collision point) after the collision. In these trials, judgments reflected a combination of the additional visual information and a Newtonian prediction based on the collision event. This was especially apparent when post and pre-collision information was inconsistent. Remarkably, when participants actively initiated the launch, the influence of the Newtonian prediction increased, in comparison with passively viewing.

Extracting Self-Motion and 3-D Depth Information From 2-D Video Sequences Using the Properties of Primate Motion-Sensitive Neurons

John Perrone[1] and Michael Cree[2]
[1]Department of Psychology, The University of Waikato, New Zealand
[2]Department of Engineering, The University of Waikato, New Zealand

Humans are very good at extracting three-dimensional (3-D) depth and self-motion information from two-dimensional (2-D) movies. Replicating this ability in a video-based sensor would greatly assist in the control of autonomous vehicles/robots. In order to emulate this amazing ability in software a rotation-free vector flow field (image velocities) must be derived. We have previously developed a system based on extra-retinal signals which removes known eye-head generated image rotation from the flow field and which estimates heading using a template model based on MSTd neurons. However, this mechanism does not work when the rotation is caused by movement along curved paths. We have now solved this problem and can estimate curvilinear rotation. This enables us to solve the 3-D from 2-D problem for the majority of self-motion scenarios. We tested this system using eight frame video movies from a camera mounted on a pan-tilt unit and moving along rails. The output point clouds successfully indicated the structure of the 3-D input.

Who's Chasing Whom?: Changing Background Motion Reverses Impressions of Chasing in Perceived Animacy

Benjamin van Buren and Brian Scholl
Department of Psychology, Yale University, CT, USA

Motion can be a powerful cue to animacy, causing even abstract shapes to be perceived as alive and goal directed. Researchers studying perceived animacy have traditionally focused on objects' local motions, but what may really matter is how they move with respect to their surroundings. Here, we demonstrate how movements signaling animacy in one context may be perceived radically differently in another context. Observers viewed animations containing a stationary central disc and a peripheral disc, which moved around it haphazardly. A background texture moved behind the discs. The direction of the background motion profoundly influenced people's objective ability to detect chasing—and could even change which disc was seen as chasing which. These dramatic effects indicate that spatiotemporal patterns signaling animacy are detected with reference to a scene-centered coordinate system, and they emphasize the incredibly potent role of context in driving the perception of life.

Temporal Dynamics of the Networks for Body Motion Processing at 9.4T

Marina Pavlova[1], Michael Erb[2], Gisela Hagberg[2], Alexander N. Sokolov[3], Andreas Fallgatter[1] and Klaus Scheffler[4]
[1]Department of Psychiatry, University of Tuebingen, Germany
[2]Department of Biomedical Magnetic Resonance, University of Tuebingen, Germany
[3]Department of Women's Health, University of Tuebingen, Germany
[4]High-Field Magnetic Resonance Center, Max Planck Institute for Biological Cybernetics, Germany

By means of ultrahigh field 9.4T magnetic resonance imaging (MRI), we conducted whole-brain functional MRI in healthy volunteers during performance of a two-alternative forced choice task with upright and inverted biological motion (BM). Neither with upright nor inverted orientations single components of point-light BM trigger body recognition. We revealed differences in the brain circuits underpinning upright and inverted BM processing, which may be summarized in terms of hemispheric laterality and anteroposterior brain axis: inverted BM activates left anterior networks engaged in decision-making, whereas readily recognizable upright BM activates solely right posterior areas. In addition, we implemented several strategies for uncovering ensembles of regions playing in unison such as temporal contrasts analysis and independent component analysis. For the first time, we uncovered distributed ensembles of regions playing in unison. The outcome provides novel insights on the networks underlying BM processing as an essential part of the social brain.

The Relative Role of Visual Self-Motion Feedback and Biological Sex Identification on the Sense of Self

Michael Barnett-Cowan[1], Aubrieann Schettler[2], Ian Holstead[3] and John Turri[2]
[1]Department of Kinesiology, University of Waterloo, Canada
[2]Philosophy and Cognitive Science Program, University of Waterloo, Canada
[3]Department of Computer Engineering, University of Waterloo, Canada

What constitutes the sense of self? We assessed the relative role of biological sex and self-motion in the visual self-representation. Participants wore a virtual reality head mounted display and interacted with pairs of avatars that visually represented the participant ("self avatar"), or a similar person but of opposite sex ("opposite avatar"). Avatar motion corresponded either with participant motion or was decoupled from participant motion. Participants indicated which avatar best represented their self overrepeated trials. Results show participants identified with "self avatars" over "opposite avatars," avatars moving congruently with self-motion over incongruent motion, and surprisingly with the "opposite avatar" over the "self avatar" when the opposite avatar's motion was congruent with the self-motion. We suggest that congruent bottom up visual feedback of self-motion is important for the sense of self, capable of overriding self-identification factors such as biological sex.

Thursday, August 30 – Special Symposia presentations

EUROPEAN SYMPOSIUM ON PERCEPTION AND ACTION IN SPORT (ESPAS)

Mauro Murgia[1], Fabrizio Sors[1], Alessandra Galmonte[2] and Tiziano Agostini[1]
[1]Department of Life Sciences, University of Trieste, Italy
[2]Department of Medicine, Surgery and Health Sciences, University of Trieste, Italy

In the last decades, the world of sport has directed its attention to the perceptual-motor processes underpinning athletes performances. Scientists, in turn, on one hand have systematically investigated how athletes perceive the cues provided by their opponents, on the other hand have tried to develop new perceptual-motor strategies to enhance sport performances. The European Symposium on Perception and Action in Sport (ESPAS) will be a special symposium, in which a strictly selected list of invited speakers coming from all over the world will present their latest findings in this area. This event will last an entire day (August 30) and will be organized in four thematic sessions: (a) methodological issues in perception and sport, (b) auditory perception in sports, (c) anticipation and contextual information, and (d) perceptual information and interceptive actions. Moreover, there will be a short oral session collecting contributions submitted by ECVP/ESPAS participants.

Virtual Reality Technology: How Can It Help Us Understand Decision-Making in Sport?

Cathy Craig
Department of Psychology, Queen's University Belfast, UK

Immersive, interactive virtual reality technology offers an exciting new way of studying decision-making in sport where the perception/action cycle is preserved. The versatility of this technology means it can be easily applied to many different sports—for example, rugby, soccer, cricket. In this talk, I will present examples from different sports and show how the dynamic patterning of visual information presented to players in a virtual environment influences their decisions about when and how to act. I will also explore how an in-depth analysis of the movement of a player as an event unfolds provides valuable insight into expert/novice differences in the decision-making process. I will explore how recent developments in VR technology offer exciting new possibilities to apply this technology to improve performance in sport.

Eye Tracking Challenges When Capturing Visual Perception in Sports Situations

José Antonio Navia Manzano
Departamento de Ciencias Sociales, de la Actividad Física y del Ocio, Universidad Politécnica de Madrid, Spain

Despite eye tracking has been prolifically employed to identify the underling mechanisms of expert performance, some issues remain unaddressed today. First, theoretical perspective adopted influences the research design. Visual patterns are sensitive to variations in the degree of the representatives of the experimental conditions. Hence, video-based interventions may not provide an accurate picture of the actual athletes' gaze behavior during the actions. Second, analyzing gaze recordings by means of visual fixations is being questioned. Neither spatial (1° to 3° of visual angle) nor temporal limits (at least 100 to 140 milliseconds) are standardized across studies. Furthermore, that minimum time of 100 milliseconds of vision is not required for movement control. Therefore, analyzing all gaze locations across a long-time scale (as the action unfolds) can actually result more fruitful in terms of identification of informational variables as well as perceptual variability assessment.

Auditory Modulation of Vision, Proprioception and Motor Behavior

Alfred O. Effenberg, Shashank Ghai, Tonghun Hwang and Gerd Schmitz
Institute for Sports Science, Leibniz University Hannover, Germany

Perceptual and motor processes and emergent representations are based on the information generated within different perceptual modalities – but also generated between modalities: Here, it is shown how auditory real-time movement-information modulates visual and proprioceptive movement perception and how subsequent motor behavior is getting shaped. Shaping motor behavior referring to intermodal information adhesion is a new approach, enabling new kinds of shaping behavioral motor patterns in sports and motor rehabilitation – even below the level of consciousness. Research was supported by European Commission H2020-FETPROACT-2014 No. 641321.

The Perception of Natural and Modulated Movement Sounds

Markus Raab[1], Nina Heims[2] and Ricarda Schubotz[2]
[1]Department of Performance Psychology, German Sport University Cologne, Germany
[2]Institute of Psychology, University of Muenster, Germany

It has been suggested that we distinguish own from other movements via internal models that are influenced by the perceiver's own movement experience. In three studies, participants are tested (a) to distinguish between self- versus other-produced movement sounds from a previously recorded hurdling performance, (b) to differentiate movement sounds that vary in the rhythmic step structure or amplitude range, and (c) to optimize the use of acoustic reafferences in movement performance. The results reveal that participants were able to (a) distinguish between their own and others' movement sounds, however, (b) changing either rhythmic step structure or amplitude range of the sounds did not influence this self- other discrimination, whereas (c) providing systematically own movement sounds let participants to improve performance. We suggest that identification of one's own movement sounds is holistically achieved as an auditory Gestalt.

Auditory Information Significantly Contributes to the Anticipation of Shot Power in Ball Sports

Fabrizio Sors[1], Mauro Murgia[1], Ilaria Santoro[1], Alessandra Galmonte[2] and Tiziano Agostini[1]
[1]Department of Life Sciences, University of Trieste, Italy
[2]Department of Medicine, Surgery and Health Sciences, University of Trieste, Italy

It is well-established that visual information has a crucial role in sport, as its correct interpretation promotes accurate predictions concerning actions outcomes. Recent studies highlighted that also auditory information provides relevant cues in various sports. A series of experiments will be presented in which, by means of temporally occluded stimuli, the contribution of early visual and auditory information to the anticipation of shot power in soccer and volleyball was compared. The first pair of experiments was based on a two-alternative forced choice paradigm, and concerned penalties and smashes; in the other three experiments, participants had to predict the length of volleyball serves. Results revealed that, when relying on auditory information, participants performed either at the same level than when relying on early visual information, or in some cases even better. These outcomes bring further support to the emerging significant role of auditory information in sport.

New Directions in Research on Perceptual-Cognitive Expertise

Mark Williams
Department of Health, Kinesiology and Recreation, University of Utah, UT, USA

A brief historical overview of research focusing on the topic of anticipation in sport is presented. The key perceptual-cognitive skills underpinning anticipation are highlighted, with discussion of how these interact and vary in importance based on various task and situational constraints. While acknowledging the large body of literature that exists focusing on the importance of perceiving kinematic information from an opponent during anticipation (i.e., the pick-up of postural cues), the relative paucity of research focusing on the importance of non-kinematic information related to situational context and other high-level cognitive factors are highlighted. Suggestions for future research work to examine the interaction between these two categories of information are presented and the implications of recent findings for research design and conceptual development in the field discussed.

Perception and Action in Context

Rouwen Cañal-Bruland
Department of Sport Psychology, Institute of Sport Science, University of Jena, Germany

In sports, athletes perform in task-specific contexts. These contexts constantly change and carry information about the probability of the occurrence of certain events. To date, research on how contextual information modulates perception-action-couplings is relatively scarce. In my talk, I will present a series of experiments in which my collaborators and I started to examine if and how online visual information and probability information are integrated to guide athletes' action planning and execution.

Knowledge Is Power? The Effect of Probability Information on Response Bias and Discriminability Between Genuine and Deceptive Sport Actions

Robin Jackson
School of Sport, Health and Exercise Sciences, Loughborough University, UK

High-skilled sport performers are much better than less-skilled counterparts when perceiving deceptive intent in their opponents. Researchers have shown they are also better at using situational probability information to respond more efficiently when action outcomes are congruent, as opposed to incongruent, with expectations. Here, I examine the effect of prior expectations on the ability of participants to discriminate between 'genuine' and deceptive actions. Signal detection analysis is conceptually well aligned with this task, yielding measures of discriminability and the degree to which prior knowledge biases performer responses. I will discuss results that call into question the value of probability information, revealing (a) lower discriminability as the strength of probability information increases and (b) strengthening of the bias towards responding to the initial intention conveyed by the action but only when the (apparent) intention is congruent with expectations.

Fractional-Order Information in the Visual Control of Locomotor Interception

Reinoud Bootsma[1], Remy Casanova[1] and Frank Zaal[2]
[1]Institute for Movement Sciences, Aix-Marseille University, France
[2]Center for Human Movement Sciences, University of Groningen, the Netherlands

Work on locomotor interception – contacting a moving target by means of whole-body displacement – has converged onto a limited set of strategies. During pursuit, the agent continuously moves in the current direction of the target (nulling angular eccentricity), while interception is accomplished by keeping the target's bearing constant (nulling angular velocity). For catching fly balls, a strategy of nulling angular acceleration has been proposed. Available information is thus generally conceived as (and limited to) integer-order time derivatives (pos = 0, vel = 1, acc = 2). In this contribution, we will present experimental work demonstrating that observed behaviour indicates situation-dependent reliance on information of intermediate order, requiring combinations of Orders 0 and 1 for straight and Orders 1 and 2 for curving target trajectories. We argue that such (mostly unprincipled) combinations might advantageously be replaced with a fractional-order conception of information.

Predictive Visual-Motor Strategies Developed by Expert Athletes When Hitting a Ball

David Mann
Department of Human Movement Sciences, Vrije Universiteit Amsterdam, the Netherlands

Skilled batters in fast-ball sports do not align their gaze with the ball throughout ball-flight but instead rely on a unique sequence of eye and head movements. In this presentation, I will demonstrate the strategies relied on by some of the world's best cricket batters when hitting a ball. When the ball follows a straight trajectory, expert batters are characterised by more predictive eye movements and better egocentric tracking of the ball. However, there are profound changes in visual-motor behaviour when the ball instead follows a curvilinear trajectory, with gaze becoming less predictive irrespective of the skill level of the batter. Crucially, approximately half of the changes when hitting curvilinear trajectories can be attributed to the uncertainty generated by the possibility of a variation in trajectory rather than any actual change in trajectory, demonstrating the influence of top-down expectations on even expert gaze behaviour.

Real-Time Audio-Feedback for Improving Motor Performance

Nina Schaffert and Klaus Mattes
Institute of Human Movement Science, University of Hamburg, Germany

Real-time audio-feedback has proven to be effective in enhancing motor perception, control, and learning because its real-time availability can serve as an external guidance for motor execution. Research in neuroscience indicates strong physiological associations between auditory and motor areas across a variety of cortical, subcortical, and spinal levels for enhancing motor performance. The perception of additional audio-feedback driven by dynamic or kinematic movement parameters supports perceptual-motor representations by enhancing cross-modal stimulation, multisensory integration, internal motor simulation, and neural plasticity. Entrainment accrues due to the fast and precise processing of temporal information in the auditory system. The potential of using audio-based feedback-system for improving performance in sport and rehabilitation will be discussed on the basis of a perception-action approach to sonification, and practical applications within a sport context presented.

Coordinating Interception and Throwing Actions Using Auditory Information in the Absence of Vision

Matthew Rodger
School of Psychology, Queen's University Belfast, UK

Many sporting skills require movements to be coordinated with static and dynamic targets in the environment, such as throwing or catching. Although vision is traditionally studied as the main perceptual modality for achieving this, auditory perception can also support coordinating action in sporting contexts. This presentation will report on experiments investigating interception and throwing actions based on acoustically specified targets, involving children and adults with visual-impairments, as well as blind-folded sighted comparators. Initial results show that participants are generally able to use acoustically specified targets to coordinate these different actions, while differences in movement strategies between sighted and visually impaired participants suggest effects of long-term adaptation to vision loss in coordinating movements with sound. These studies explore the extent to which auditory perception can support pick-up of action-relevant information in the absence of vision.

Expert Players Accurately Detect an Opponent's Movement Intentions Through Sound Alone

Ivan Camponogara[1], Matthew Rodger[2], Cathy Craig[2] and Paola Cesari[3]
[1]Department of Psychology, New York University Abu Dhabi, UAE
[2]School of Psychology, Queens' University Belfast, UK
[3]Department of Neurological, Biomedical and Movement Sciences, University of Verona, Italy

Sounds offer a rich source of information about events taking place in our physical and social environment. However, little is known about whether humans can recognize and act upon the intentions of another agent's actions detected through auditory information alone. In this study, we shed some light on whether intention can be inferred from the sound of an action by means of asking experienced and novice basketball players to virtually intercept an attacker while listening to audio recordings of that player's deceptive and nondeceptive movements. We showed that basketball players were able to more accurately predict final running direction compared to nonplayers and anticipate the attacker intentions by picking up and use the relevant kinematic features of deceptive movement from event-related sounds. This suggests that action intention can be perceived through the sound a movement makes and that this ability is honed through practice.

Expertise Differences in Identifying the Direction of an Opposing Footballer's Moves: A Behavioural and Event-Related Potentials Study With Point-Light Stimuli

Michael Wright[1] and Robin Jackson[2]
[1]Department of Life Sciences, Brunel University London, UK
[2]School of Sport, Exercise & Health Sciences, Loughborough University, UK

Although their EEG was recorded, skilled and novice footballers viewed temporally occluded point-light video clips of opponents dribbling the ball towards the viewer then turning to the left or right, either without deception (50% of trials) or with a stepover action to feign moving in one direction before going in the other (50% of trials). Skilled footballers showed overall superior judgement of final direction (d′) based on early body kinematics. Event-related EEG alpha band-power (9–11 Hz) was greater in experts than novices both before and during the video. However, relative to the pre-stimulus peak, there was greater alpha desynchronization during action observation in experts and for deceptive than for non-deceptive actions. Event-related potential data also showed greater amplitude of a CNV-like frontal negativity in skilled players than novices. Expertise in perceiving deceptive intent thus affected EEG measures both during action observation and at the response preparation or expectancy stage.

Brain Dynamics During Action Anticipation Processes: A Study Protocol

Sergio Costa[1], Pierpaolo Croce[2], Maurizio Bertollo[3] and Filippo Zappasodi[2]
[1]ITAB, Università Gabriele d'Annunzio, Italy
[2]Department of Neuroscience, Imaging and Clinical Sciences, Università Gabriele d'Annunzio, Italy
[3]Department of Medicine and Aging Sciences, Università Gabriele d'Annunzio, Italy

The stimulus identification and response selection are on the basis of the visual anticipation and play a crucial role for the decision-making in tennis. To investigate this process, we have developed a study protocol with the purpose of characterizing the dynamics of the brain activity, presenting a series of videos to the participants, simultaneously recording high density EEG (128 channels). Videos, presented in both two-dimensional and three-dimensional modalities, show an athlete who is hitting a forehand or a backhand stroke in four different areas of the court, and the videos present spatial and temporal occlusion. The participants will press, as fast and accurate as possible, a four different keyboard keys to anticipate in which of the four court zones the ball will end. Beside behavioral data, cortical activity will also be evaluated during the visual anticipation task in terms of reaction time, evoked responses, and modulation of brain rhythms in alpha, theta, and beta bands.

Emergent Coordination in Joint Interception

Frank Zaal[1], Daphne van Opstal[1], Niek Benerink[2], Remy Casanova[2] and Reinoud Bootsma[2]
[1]Center for Human Movement Sciences, University of Groningen, the Netherlands
[2]Institut des Sciences du Mouvement, Aix-Marseille Université, France

In many situations, in daily life, people show coordinated behaviour to attain a shared goal. In the present contribution, we consider a "double-pong" task, modelled after sports situations in which teams of players have to intercept a ball (e.g., receiving a volleyball serve). In the "double-pong" task, two players each control a paddle on a shared screen. Their task is to make sure that a ball that moves from the top to the bottom of the screen will be intercepted by one on them, also avoiding a collision between the paddles. We suggest that the division of labour between the two players emerges from the continuous visual coupling of the player-controlled paddles and the ball. That is to say, on many trials both players initiated a movement, which was aborted by one player when the other player was on an interception course, specified through the changing triangular relation among ball and paddles.

Both Eye Tracking and Manual Control Performance Predict Batting Accuracy in Experienced Professional Baseball Players

Li Li[1] and Rongrong Chen[2]
[1]Department of Neural Science, New York University Shanghai, China
[2]Department of Psychology, The University of Hong Kong, China

We examined whether baseball players have superior eye tracking and manual control capabilities and how they relate to real-world batting. First, we tested professional baseball players from Hong Kong leagues ($n = 44$) and demographically matched nonathletes ($n = 47$) using an eye-tracking task in which participants visually tracked step-ramp motion that varied in both speed and direction from trial to trial. Next, we used a manual control task in which participants used a joystick to center a randomly

moving target. Last, we measured real-world batting performance. Our sample of professional baseball players showed superior eye-tracking and manual control capabilities, as well as coordination between eye–hand control absent in nonathletes. Our results demonstrate that both eye tracking and manual control performance predict batting for more-experienced but not less-experienced baseball players, suggesting that real-world batting develops within visuomotor limits.

Predicting Ball Direction From Compact Representation and Classification of Whole-Body Throwing Actions

Antonella Maselli[1], Aishwar Dhawan[2], Benedetta Cesqui[3], Marta Russo[3], Francesco Lacquaniti[3] and Andrea d'Avella[4]
[1]Neuromotor Physiology Lab, Fondazione Santa Lucia, Italy
[2]Department of Biomechanics, Institute of Sukan Negara, Malaysia
[3]Department of Systems Medicine and Center of Space Biomedicine, University of Rome Tor Vergata, Italy
[4]Department of Biomedical and Dental Sciences and Morphofunctional Imaging, University of Messina, Italy

Smooth interpersonal interactions rely upon predictive skills that compensate for sensorimotor delays. Throwing-catching tasks can be used to investigate the sensorimotor mechanisms involved in such predictions. As previously shown, the whole-body kinematics of a throw can inform about the outgoing ball direction up to 500 milliseconds before ball release via body segments that vary across individuals. With the aim of characterizing interindividual differences in the throw predictability, we introduced a novel low-dimensional description of individual throwing kinematics. This description allows for robust identity recognition and, through a clustering algorithm, classification of throwing actions into four main throwing styles. These styles are recurrent across individuals and can identify through time the most informative body segments for predicting the ball trajectory before release. We present these results together with related implications for human–human and human–robot interaction.

Employing Adaptive Working Memory Training to Improve the Quiet Eye and Tennis Performance Under Pressure

Emmanuel Ducrocq[1], Mark Wilson[2] and Nazanin Derakshan[1]
[1]Department of Psychological Science, Birkbeck, University of London, UK
[2]Department of Sport and Health Sciences, Exeter University, UK

Optimum levels of attentional control are essential to prevent athletes experiencing performance breakdowns in high-pressure contexts. The pre-study explored if training attentional control using the adaptive Dual N-back task targeting processing efficiency of the main executive functions of working memory would result in transferable gains on sports performance outcomes. A sample of tennis players undertook 10 days of training on the adaptive Dual N'Back task with pre- and post-tennis performance being assessed on a volleying task performed under pressure whilst their gaze behaviour was recorded. Results showed benefits of training on working memory capacity, tennis performance and on the quiet eye. Our results indicate that training the updating, inhibition and shifting functions of working memory enhanced the ability to maintain effective attentional control to improve tennis performance extending previous research exploring the benefits of cognitive training on sports performance.

On the Perception of "Flow" in Action and Adventure Sport Athletes: Individual Differences in "Mindfulness" Predict the Likelihood of Negative Consequences

Brent Hogarth[1] and David H. Peterzell[2,3]
[1]Department of Psychology, John F Kennedy University, CA, USA
[2]University of California, Berkeley, CA, USA
[3]John F Kennedy University, CA, USA

"Flow" is a perceptual state often associated with optimal performance. But athletes' attempts to achieve flow can involve risky behaviors with negative consequences. Wingsuit flying, for example, involves high rates of addiction, injury, and death. Mitigators of flow's consequences need investigation. Does variability in "mindfulness" predict emotion dis-regulation, poor self-control, addiction, exercise dependence, and perceptual errors? Sixty action and adventure sport athletes participated, scoring >3 on the Short Dispositional Flow Scale-2. They completed the Five Facet Mindfulness Questionnaire (FFMQ-15), Brief Self-Control Scale, Difficulties in Emotion Regulation Scale -Short Form, and Exercise Dependence Scale–Revised. Variability in Mindfulness traits correlated positively with Self-Control and negatively with Difficulties in Emotion Regulation. Further research will investigate if mindfulness-based interventions reduce flow's negative consequences in high-risk athletes.

PERCEPTUAL STRUCTURES – A FESTSCHRIFT FOR MICHAEL KUBOVY

Marco Bertamini
School of Psychology, University of Liverpool, UK

This symposium is organised on the occasion of Michael Kubovy's retirement. Anyone who knows Michael will not be surprised that the scope of the symposium is broad. Michael has made seminal contributions to our understanding of vision, audition, and their interaction, as well as to psychology of art, and philosophy of mind. The name of this symposium ("perceptual structures") is inspired by the Gestalt tradition, which Michael helped to reinvigorate in the 1980s, and whose modern incarnation is sometimes called neo-Gestalt. The symposium includes work on perceptual organisation and grouping (Pomerantz, Wagemans and Gepshtein), contour integration (Maloney), neurophysiological correlates of structures such as dot lattices (van Leeuwen) or symmetry (Bertamini) and phenomena related to human interaction with music (Schutz), photos (Bruno) and films.

Measuring Gestalts

James R. Pomerantz
Department of Psychology, Rice University, TX, USA

We all know Gestalts when we see them, but how can psychologists measure them? The challenge of measuring perceptual experiences has been with us since Weber and Fechner launched psychophysics, but the problem deepens when we attempt to analyze and quantify perceptual wholes. Michael Kubovy has helped us think through this thorny problem, including with his spirited affirmation of phenomenological psychophysics as a diagnostic for perceptual organization. Here, I review some methods that have been used by Kubovy and others to diagnose when perceptual grouping occurs, and two attempts to quantify grouping on a common scale of measurement. Fortunately, these methods usually lead to similar conclusions, thereby providing strong converging operations to support our theories.

Perceptual Grouping in Dot Lattices Revisited

Johan Wagemans
Brain & Cognition, KU Leuven, Belgium

Kubovy et al. quantified grouping by proximity and similarity in dot lattices. They heavily relied on phenomenological psychophysics: systematically manipulating the stimulus parameters and recording the corresponding percepts. We sought to extend this pioneering work in two ways. First, we convincingly replicated the findings by Kubovy et al. on grouping by proximity by asking observers about perceived orientation, and we confirmed them by measuring performance in a match-to-sample experiment. Second, we convincingly replicated the findings by Kubovy and van den Berg on grouping by proximity and similarity, and we explored individual differences by using order-constrained hierarchical modelling and mixture modelling. In general, our work shows that phenomenal psychophysics can be meaningfully related to more traditional approaches in psychophysics and vision science as well as to the more recent emphasis on individual differences.

Perceptual Organization of Space Between Objects

Sergei Gepshtein
Center for Neurobiology of Vision, Salk Institute for Biological Studies, CA, USA

From seminal ideas by Gestalt psychologists to modern work in the Gestalt tradition, studies of perceptual organization focus on perception of objects. The "shapeless ground" that fills the space between objects has remained a secondary affair. I argue, we neglected perceptual "ground" because we tend to ask how solid forms and layered precepts arise from two-dimensional patterns. The situation is different for a perceiver moving in the space between objects. Far from shapeless, the space has an intricate structure made of three-dimensional ("solid") regions that contain different potential percepts. The solid regions have well-defined shapes determined by selectivity of the perceiver's sensory systems. I show how the shapes and locations of these regions are predicted for visual perception and describe a first series of experiments testing the predictions. I contrast the notion of perceptually organized space with the notions of "ambient light array" in ecological optics and "light field" in computer graphics.

Dot Lattices and Brain Dynamics

Cees van Leeuwen
Laboratory of Experimental Psychology, University of Leuven, Belgium

Michael Kubovy's work on ambiguous dot lattices has shown that perceptual grouping preferences depend quantitatively on proximity. Our EEG studies reveal that proximity grouping is a multistage process, irreducible to a single mechanism localized anatomically or chronometrically. Proximity sensitivity correlated positively with amplitude of the earliest event-related potential peak, C1, reflecting early feed-forward processes, and negatively

with the next peak, P1, reflecting lateral and feedback interactions. This peak involved beta band synchronization, related to proximity sensitivity and inversely related to stimulus ambiguity. Prestimulus activity showed alternating modes of low and high alpha power. In the former mode, responses were biased towards the vertical orientation, irrespective of proximity; in the latter, proximity-based responses were dominant. Biased responses, and their association with alpha power, vanished over the course of the experiment.

Perception of Symmetry: Psychophysics, Neuroscience and Aesthetics

Marco Bertamini, Alexis Makin and Giulia Rampone
School of Psychology, University of Liverpool, UK

Visual symmetry has a special role in vision. As a term that refers to the regularities and structure in the image, it can be used to study the functional role of visual regularities. Tuning to symmetry is well documented (responses are fast and robust). More recently, an extrastriate network of areas has been identified that is active when symmetry is present in the image. This response is largely automatic, although when symmetry can only be recovered after slant normalisation or over time, then the network is engaged only when symmetry is actively selected by the observer. Neural activation and behavioural measures go hand in hand, for example, in confirming that certain regularities are special (namely, reflectional symmetry). I will review and summarise the more recent results and conclude with a reflection on the link between perception and visual preference formation.

On the Pleasures of Canned Laughter

Heiko Hecht and Andreas Baranowski
Department of Psychology, Justus Liebig-Universität Giessen, Germany

TV stations often choose to add laugh-tracks to their shows. If such a simple manipulation can change our attitudes toward the film, does the opposite manipulation work as well? Do screaming voices have comparable effects in the opposite direction? We designed three experiments to test whether scream tracks have comparable effects. We showed segments of comedies, scary, and neutral films and crossed them with three sound tracks of canned laughter, canned screams, and no audience sound. Observers had to rate the degree of their subjective amusement and fear as well as general liking and immersion. Both canned laughter and canned screams had enhancing effects. When we manipulated social pressure by explicit evaluations of the film clips, canned laughter was particularly effective in those comedies that were only mildly funny to begin with. Thus, the information conveyed by a sound track is able to change the evaluation of a film regardless of its emotional nature.

Music Cognition and Perceptual Organization

Michael Schutz
School of the Arts, McMaster University, Canada

Although music is typically viewed as an auditory phenomenon, playing instruments with long versus short movements shapes our perception of note duration. This natural illusion contrasts with the psychophysical research suggesting audition dominates duration estimation and stems from the brain's processing of amplitude envelope (sound shape). Tones with natural decays integrate with visual information, whereas artificially decaying tones do not. This finding holds important implications, as a recent survey of 1,000 auditory psychophysical experiments illustrates a strong past focus on artificial sounds. Consequently our experimental work on the role of amplitude envelope in duration assessment strategies detecting audio-visual unity and learning sight-sound associations illustrates the vital importance of basic research on our perception of complex sounds—such as those heard in music.

Breakdown of Contour Interpolation

Laurence Maloney
Department of Psychology, New York University, NY, USA

In typical scenes, objects and parts of objects may be occluded by other objects, for example, a smoothly varying contour may pass under a rectangular. In experiments, we can challenge the observer to estimate the location of the contour under the occlude and even to set a small line tangent to the invisible contour. One difficulty in interpreting experimental results is that we have no criterion that would allow us to conclude that the observer fails. When, for example, the contour is nonrelatable, observers' estimates of location and tangent become much more variable. But how variable must settings be before we conclude that observers' are "winging it"? I will describe two criteria that each characterize a breakdown of contour interpolation and experimental tests of each. Human interpolation behavior is remarkable in its sophistication but a complete theory of how we interpolate must also predict our failures. This work was jointly done with Jaqueline M. Fulvio and Manish Singh.

Role of Visual Consciousness in Perceptual Organization

Ruth Kimchi
Department of Psychology, University of Haifa, Israel

Perceptual organization is the process by which disjoint bits of visual information are structured into a meaningful scene composed of objects and their interrelations. Can perceptual organization unfold in the absence of visual awareness? The answer to this question has turned out to be complicated. I will present studies examining different organization processes, using a priming paradigm and two methods to render the prime invisible, continuous flash suppression and sandwich masking under matched conditions. Results demonstrate: (a) some perceptual organization processes, such as grouping elements by color similarity or by connectedness into vertical/horizontal patterns can occur without awareness, whereas other processes, such as grouping elements into a global shape cannot; (b) whether a process can occur without awareness is dependent on the level at which the suppression induced by the method used for rendering the stimulus inaccessible to awareness takes place.

Perceptual Structures in Selfies

Nicola Bruno
DiMeC, Università di Parma, Italy

If factors determining visual structure in art are rooted in general psychological mechanisms, their effects should be detectable even in pseudoartistic works by nonprofessionals. I will present a series of studies testing this prediction in selfies, photographic self-portraits taken by amateurs using the digital cameras of mobile devices. Databases include both selfies produced on demand in Italian and U.K. laboratories and selfies spontaneously posted on social media from a variety of world cities. Results reveal interesting parallels in visual structures observed in selfies, painted self-portraits, and professional photographers portraits but also systematic deviations from widely held principles. Selfies are currently proving to be a rich source of naturalistic data on much studied aspects of artistic composition and visual communication.

Thursday, August 30 – Symposia presentations

3D VISION: WHAT IS THE STATE OF THE ART?

Fulvio Domini and Dhanraj Vishwanath
Department of Cognitive, Linguistic, and Psychological Sciences, Brown University, RI, USA

The question of how our perception of three-dimensional (3D) space and objects is derived from two-dimensional retinal input and then encoded in the brain has driven a significant proportion of perception research for the last several decades. Yet, fundamental questions remain largely unanswered. Traditional approaches have defined the problem of 3D vision as the derivation of a veridical and unitary 3D Euclidean structure. But classic and recent work point to the existence of multiple representations and coordinate frames in our perception of space and objects and expose the complexity of the task-dependent link between 3D visual information, its perception, and its use in the control of movement. These observations suggest a reevaluation of established models of biological 3D vision and highlights the need for new theoretical and computational frameworks. This special two-part symposium will bring together leading researchers who advocate new questions, methods, and approaches and remain deeply intrigued by the problem of 3D perception.

The Nature of Depth Cues

Barbara Gillam
Department of Psychology, University of New South Wales, Australia

It is argued that "depth cues" are not distinct modules but different ways of sampling information. For example, stereopsis is a binocular version of perspective and incorporates interocular differences in each of the different components of perspective (as illustrated by Wheatstone). Motion parallax is not only a dynamic version of stereopsis but also of perspective. It is shown empirically that differences in the effectiveness of monocular perspective cues are reflected in their binocular and motion perspective analogues. An emphasis on the mode of information pick-up has tended to dominate the literature on depth perception to the detriment of a more general analysis of the geometry of the information available about three-dimensional relations which would show the mathematical link between depth cues.

Context Dependency in 3D Shape Perception

James Todd
Department of Psychology, Ohio State University, OH, USA

There are numerous sources of optical information, such as texture, shading, motion, or binocular disparity, from which human observers are able to gain knowledge about the three-dimensional (3D) structure of the environment. One important problem that has not been adequately addressed, however, is that all of these potential sources of information are context dependent. For example, the computation of 3D shape from motion or binocular disparity is relatively easy when optical features are constrained to abrupt changes in surface orientation or reflectance, but existing models fail badly when those features consist of specular reflections or smooth occlusion contours. Similarly, humans can perceive shape from texture with either large or small amounts of perspective, but there are no existing models that can function effectively in both contexts. These observations suggest that the identification of relevant contextual factors may be a critical process for 3D vision in unconstrained natural environments.

Quadratic Rescaling of Multiple Depth Cues to a World Metric for Effective Action

Christopher Tyler
Department of Optometry, City University of London, UK

The core issue is to conceptualize the encoding of the three-dimensional structure of the world through the neural computation of the multiple depth cues and their integration to a unitary depth structure. Generic depth encoding was hypothesized by Tyler as a two-level model of local cue interactions followed by a generic depth map and validated in a series of psychophysical and functional magnetic resonance imaging studies supporting its instantiation in the form of a self-organizing neural surface representation ('attentional shroud'). In relation to the combination of surface cues, this conceptualization reveals that traditional Bayesian weighting approaches will fail without a spatial interpolation mechanism to deal with sparse and ambiguous depth cues, requiring a quadratic rescaling of all the depth cues to each other and to the unitary world metric for effective action. Both a comprehensive analysis of surface encoding properties and the time course of this rescaling process are needed to validate this two-level model.

The Need for Fresh Thinking on Cortical Processing for 3D Vision

Andrew Glennerster
School of Psychology and CLS, University of Reading, UK

Questions for this symposium include: Do we have a coherent approach to the general problem of three-dimensional (3D) vision? Is there consensus about the nature of the perceptual output or the representation of 3D information? Do we understand much about how neural mechanisms contribute to 3D processing? The answers to these questions must be a resounding 'No'. Psychophysical, imaging and neurophysiological approaches to investigating 3D vision predominantly focus on binocular vision or short-baseline motion parallax, whereas most animals achieve 3D vision by moving around freely. Consequently, these approaches have little to say about how the cortex might contribute to the representation that underlies ambulatory 3D vision. An important contrast comes from reinforcement learning. Agents are rewarded for navigating to target images but they do not build 'maps' or transform information between coordinate frames. As such, they may force us to think differently about how the cortex contributes to 3D vision.

How Are 2D and Stereoscopic 3D Information Encoded Together in Primary Visual Cortex?

Jenny Read[1], Sid Henriksen[1], Daniel Butts[2] and Bruce Cumming[3]
[1]Institute of Neuroscience, Newcastle University, UK
[2]Department of Biology, University of Maryland, MD, USA
[3]National Eye Institute, National Institutes of Health, MD, USA

With his random-dot stereogram, Julesz gave us a psychophysical scalpel which dissects out one particular cue to three-dimensional (3D) structure: binocular disparity. Because this cue is not detected until primary visual cortex (V1), stereoscopic 3D has become a model system for relating cortical activity to perceptual experience. Our increasingly sophisticated models of V1 neurons can now explain many aspects of S3D perception as well as predicting neuronal responses to previously unseen binocular images. In both neurons and models, responses depend on the particular two-dimensional (2D) image but are tuned for disparity when averaged across many images. However, compared to models, neurons (a) respond more to stimuli at their preferred disparity and (b) show more dependence on 2D image at a given disparity. Thus, real neurons show more sensitivity to both 3D disparity and 2D image patterns. Understanding how this occurs could shed light on cortical function more broadly as well as 3D perception in particular.

To Understand 3D Vision, We Must Study How Vision Is Learnt

Roland Fleming
Department of Experimental Psychology, University of Giessen, Germany

Most theories of three-dimensional (3D) vision take it for granted that the visual system's goal is to estimate physical quantities, such as depth or surface orientation. This view has two major problems: (a) How do we ever learn to see in 3D if we cannot access the ground truth? (b) Why are judgments so often inconsistent with the physical depth structure? I suggest that 3D vision is not the result of estimating physical quantities but rather emerges as a result of learning to continuously predict the visual input. Training neural networks to predict the next frame in movies does not require ground truth depths. Yet, to predict successfully, such systems must automatically learn to disentangle distal causal factors (e.g., distance, size). Importantly, the resulting representations are intrinsically related to the way those distal quantities affect proximal image structure. This potentially provides a coherent explanation of both failures and successes of human 3D vision.

3D Vision and Action

Thomas Papathomas[1], Elizabeth Torres[2] and Michael Wagner[3]
[1]Department of Biomedical Engineering, Rutgers University, NJ, USA
[2]Department of Computer Science, Rutgers University, NJ, USA
[3]Human Factors Engineering Laboratory, Ariel University, Israel

We need information from the visual system to interact with the environment. The issue of whether such visual information is provided primarily by signals from the dorsal visual stream with minimal input from the ventral stream is still under debate. Most of the psychophysical evidence comes from experiments with two-dimensional stimuli. Depth inversion illusion stimuli provide a much more natural paradigm because they enable visuomotor behavior in three-dimensional (3D) visual space. A key question is whether the motor behavior is governed by the perceived inverted depth (physically distant points perceived to be closer than physically near points) or by the veridical geometry. Data from our experiments, both for reaching and for vergence eye movements, provide strong evidence that the illusory 3D space governs motor responses. The reaching experiments revealed that this motor behavior was true not only for the deliberate forward reaching trajectory but also for the spontaneous return movements.

Understanding the Perception of Vast Spaces

Jeanine Stefanucci[1], Roberta Klatzky[2] and William Thompson[3]
[1]Department of Psychology, University of Utah, UT, USA
[2]Department of Psychology, Carnegie Mellon University, PA, USA
[3]School of Computing, University of Utah, UT, USA

Standing on a beach looking out to sea can make observers feel as though the space around them extends without limit. Philosophers have described this as a sense of vastness. But what are the perceptual mechanisms that denote such large extents to observers? Primary and secondary depth cues can be used to perceive scale in three-dimensional (3D) spaces of $\sim$1 km or less, but they cannot explain how people perceive scale in vast spaces where all of the classical depth cues become ineffective. Thus, an open question in 3D vision is whether there is a distinction between the perception of the overall scale of a space and the perception of absolute distance and size in that space. Addressing this question requires new measures to assess perception of vast spaces. Results from preliminary investigations of these questions are intriguing but so far have generated more questions than answers. Virtual environments may be an especially useful tool in helping to answer some of these open questions.

Towards a 3D Visual Reasoning Challenge for Machine Vision

Thomas Serre
Department of Cognitive, Linguistic, and Psychological Sciences, Brown University, RI, USA

Recent progress in computational vision has been significant. Modern deep neural network architectures solve many visual recognition tasks from face identification and object recognition to depth estimation with impressive accuracy. At the same time, modern neural networks are known to generalize poorly to novel contexts. For instance, we have found that state-of-the-art neural networks trained to estimate depth from large databases of images paired with ground-truth depth maps break down when presented with inverted image stimuli or novel classes of objects not used during training. Are these differences between human observers and computer algorithms due to differences in the computational strategies employed or due to differences in the richness of their visual experiences? Our hope is to stimulate a discussion toward assessing the capabilities of modern machine vision architectures against human behavioral data on a level playing field.

An Early Experimental Investigation of Central and Peripheral Vision by Ibn al-Haytham (Alhazen)

Gül A. Russell[1], M.I. Russell[2] and Ian I. Steele-Russell[1]
[1]College of Medicine, Texas A&M University, TX, USA
[2]Department of Computer Science and Engineering, Texas A&M University, TX, USA

In his Book of Optics (Kitāb al-Manāẓir), Ibn al-Haytham (d. 1040; Latin Alhazen) identified the essential requirements for binocular integration of images, one from each eye, in the common nerve (chiasma) with reference to convergent and conjugate eye movements to preserve point-to-point correspondence. Even when fused, the images were not uniformly perceived, nor necessarily distinct. In a series of experimental demonstrations, using a specially designed board (based on Ptolemy), with a fixation point, and visual targets, he systematically investigated how and why this occurred. He tried to isolate the variables responsible for the degradation of images in the peripheral compared with those in the central visual field. The fundamental importance of the questions he raised and the explanations he provided will be discussed as part of his effort to establish "unchanging, invariant" principles in visual optics and evaluated within a historical context.

ENSEMBLE PERCEPTION IS MORE THAN AVERAGES

Gianluca Campana[1], Andrey Chetverikov[2] and Árni Kristjánsson[3]
[1]Department of General Psychology, University of Padova, Italy
[2]Donders Institute for Brain, Cognition and Behaviour, Radboud University, the Netherlands
[3]Faculty of Psychology, University of Iceland, Iceland

We often think of objects using single-label features: a green apple, a thick branch, and a dark shadow. Yet, in a real world, each object's features have some variability. A green apple might have spots of yellow, a thick branch varies in thickness along its length, and so on. Previous work in ensemble perception has demonstrated that humans and other animals are apt at encoding the average feature values from perceptual ensembles that could explain our ease at using simple labels. But how does the visual system deal with variability in ensemble perception? Is it discounted to save resources, leaving us with the averages only? Is it approximated using some simple model, such as normal approximation or just an estimate of range? Or is it encoded in a relatively detailed way, leaving us with the knowledge of probability distributions of features? We aim to discuss the evidence pointing to different answers to these questions and to see whether different results can be explained by differences in empirical approaches.

Uncertain Stimulus Representations Aid the Learning of Their Distributions

Andrey Chetverikov[1], Gianluca Campana[2] and Árni Kristjánsson[3]
[1]Donders Institute for Brain, Cognition and Behaviour, Radboud University, the Netherlands
[2]Department of General Psychology, University of Padova, Italy
[3]Faculty of Psychology, University of Iceland, Iceland

Within traditional psychophysics, researchers typically rely on explicit judgments to estimate representations of visual ensembles. Such methods, however, may confound the precision of task-based abilities for accessing representations with the representations themselves. Recently, we introduced a new implicit approach to estimate such representations, based on the build-up and break-down of expectations in visual search, avoiding problems associated with explicit judgements. Following a brief review of key results from this approach, I discuss how uncertainty about the individual items in visual ensembles affects resulting representations. In the orientation domain, individual items are represented more precisely when they are closer to the cardinals, but observers represent distributions more precisely away from the cardinals. We suggest that uncertainty at lower levels of hierarchical probabilistic representations might be compensated for by more accurate higher level representations.

Explicit and Implicit Judgments of Distribution Characteristics: Do They Lead to Different Results?

Sabrina Hansmann-Roth[1], Árni Kristjánsson[1], David Whitney[2] and Andrey Chetverikov[3]
[1]Department of Psychology, University of Iceland, Iceland
[2]Department of Psychology, University of California, Berkeley, CA, USA
[3]Visual Computation Lab, Donders Institute for Brain, Cognition and Behavior

Objects have a variety of different features that can be represented as probability distributions. Previous findings show that besides mean and variance, the visual system also encodes distribution shape. Visual search studies showed how previously learned properties of distractor distributions influence search times where the underlying shape of the distribution was assessed through RT changes. Here, we compare this implicit method with explicit judgments of mean, variance, and higher order statistics from a two-alternative forced choice (2-AFC) task. Subjects

learned particular properties of distractor distributions over trials and then compared two distractor sets of varying mean and variance. Results from the 2-AFC task yielded much noisier representations than our implicit method. Analyzing the learning of particular properties of the distractor distributions between the two methods reveal the costs and benefits of explicit and implicit judgments as tools to assess internal representations of feature distributions.

Optimal Variance Encoding of Contours in Naturalistic Images

Jozsef Fiser[1], Jeppe Christensen[2] and Peter Bex[3]
[1]Department of Cognitive Science, Central European University, Hungary
[2]Department of Psychology, University of Copenhagen, Denmark
[3]Department of Psychology, Northeastern University, Boston, MA, USA

We investigated feature ensemble encoding at the lowest level of visual processing by focusing on contour encoding in natural images. In such images, the mean contour is not a single value, but it varies locally with spatial position and variability of the contour can be quantified by the noisiness of the contour segments. We used a novel image decomposition/recomposition method, three different classes of images (circular patterns, object, and fractal images), and two types of noise (orientation and position noise) to generate stimuli for a two-alternative forced choice pedestal noise discrimination task. We found that humans readily encoded variability of contour ensembles, this encoding systematically varied with image classes, and it was distinctively different for orientation versus position noise despite participants not being able to reliably distinguish between the two types of noise. Moreover, JND obtained with mixed orientation and position noise followed the optimal maximum likelihood estimate, supporting a probabilistic coding of contours in humans.

Amplification in Ensemble Perception

David Whitney[1], Shoko Kanaya[2] and Allison Yamanashi-Leib[1]
[1]Department of Psychology, University of California, Berkeley, CA, USA
[2]Graduate School of Frontier Biosciences, Osaka University, Japan

Humans are sensitive to information about collections of objects via ensemble or summary statistical representations. Ensemble perception is efficient and provides rich information ranging from low-level features to visuosocial cues. It also provides emergent information that is not available at the level of any individual object. One frequently encountered but puzzling emergent summary statistical percept is an amplification effect: The perceived average in a crowd of objects is sometimes exaggerated. This occurs for average object size, average object and face attractiveness, average temporal frequency, and even judgments of average value or price of a crowd of objects. Ensemble amplification is not specific to spatial information or low-level features but seems to be a persistent characteristic of visual ensemble coding. Here, we consider the possible reasons for the amplification of ensemble percepts, which we will argue help constrain the nature of ensemble coding models.

The Role of Ensemble Summaries in the Segmentation and Categorization of Multiple Intermixed Items

Igor Utochkin
Department of Psychology, National Research University Higher School of Economics, Russia

Ensemble representations, such as of the mean of ensembles, are assumed to provide a good approximate summary of individual properties of multiple objects. But a single summary statistic is not very informative when we encounter intermixed objects of different kinds. For example, if we evaluate the mean redness of berries on a bush, we should ignore the greenness of surrounding leaves to avoid bias. This implies that the berries and the leaves should be parsed into separate categorical groups prior to color averaging. I will present a simple theory explaining how the visual system can use ensemble statistics to rapidly decide whether all items in a scene are drawn from a single type or from different types. The shape properties of feature distributions and, in particular, the number of distinct peaks, are assumed to play a key role, each corresponding to a likely "category." Recent empirical evidence for this mechanism from various paradigms will be reviewed.

Representing Motion Ensembles in Early Visual Cortices

Gianluca Campana[1], Árni Kristjánsson[2], Rita Donato[1] and Andrey Chetverikov[3]
[1]Department of General Psychology, University of Padova, Italy
[2]Faculty of Psychology, School of Health Sciences, University of Iceland, Iceland
[3]Donders Centre for Cognitive Neuroimaging, Radboud University, the Netherlands

We have recently shown that humans can represent not only single features or just summaries of feature ensembles but the shape of whole feature distributions (i.e., the probability density function—PDF of particular stimulus dimensions). Observers are, in other words, able to learn the

shape of distractor distributions, not only their mean and variance. This has been demonstrated with both orientation and colour. Here, we assess (a) whether motion ensembles are also coded by representing the distribution of motion directions and (b) where the representations of these distributions occur in our brain. By using repetitions of distractor distributions and role-reversals in a visual search task involving the identification of the oddly moving target, we found that observers can build representations of distractor distributions, but the learning is limited by motion repulsion, thus producing a distorted representation of PDFs. Moreover, by using TMS between trials over early visual cortices, we were able to interfere with the learning of ensemble representations of visual motion.

DEEP NEURAL NETWORKS: THE NEW BENCHMARK MODEL OF VISUAL OBJECT RECOGNITION

Astrid Zeman
Brain and Cognition, KU Leuven, Belgium

The performance of deep neural networks (DNNs) has met, and surpassed, that of human object recognition. Researchers are recruiting DNNs to imitate, investigate, and interrogate how the brain processes visual information. We have gone beyond simple analogies between computers and humans to comprehensively comparing artificial brains with biological ones. We are no longer simply comparing the accuracy of DNNs versus animals on visual tasks, but we are examining more nuanced questions. These queries address some of the fundamental uncertainties regarding how the brain learns, stores, and transforms visual input from the eye to higher level representations, layer upon layer along the visual pathways. This symposium details some of the recent advances at the interface of biological and machine vision, offering a fresh outlook on understanding vision with this promising and exciting new tool.

Semantic Category Versus Shape Representation in Deep Neural Networks and the Ventral Visual Pathway

Astrid Zeman, J. Brendan Ritchie, Stefania Bracci and Hans Op de Beeck
Brain and Cognition, KU Leuven, Belgium

Deep neural networks (DNNs) have reached human-level performance in categorising objects from images, becoming the new benchmark model of biological object recognition. One open question is whether DNNs learn category semantics, or exploit low-level properties of objects, such as shape, to classify images, since shape and category are highly correlated in natural images. Taking two stimulus sets that orthogonalise category and shape, we investigate the interaction between these two types of information in high-performing DNNs and correlate artificial with neural representations along the human ventral visual stream. We find that early layers of DNNs encode shape, correlating highest with V1. Semantic categories, and the animate-inanimate division, are best represented by late layers of deep networks, which correlate highest with anterior ventral temporal cortex. In sum, our results suggest that DNNs represent semantic categories independently from shape.

Architecture Matters: Training and Structure Both Affect How Well Deep Networks Predict Cortical Representations of Objects, Places and Faces

Katherine Storrs[1], Johannes Mehrer[2], Alexander Walther[2] and Nikolaus Kriegeskorte[3]
[1]Department of Psychology, Justus-Liebig Universität, Germany
[2]MRC Cognition and Brain Sciences Unit, University of Cambridge, UK
[3]Zuckerman Mind Brain and Behavior Institute, Columbia University, NY, USA

We use representational similarity analysis to test how well seven deep convolutional neural networks (DCNNs) predict functional magnetic resonance imaging representations of object images in human inferotemporal cortex (IT). Before training, randomly initialised nets already explain significant IT variance. After object-classification training, correlation with IT diverges across architectures and is not predicted by either network depth or object classification accuracy. A 22-layer InceptionNet predicts IT better than state-of-the-art Deep Residual networks (50–100 layers). Training on domain-specific tasks improves prediction of IT subregions; a DCNN trained to identify faces best predicts representations in the Fusiform Face Area, while the same architecture trained to classify scenes best predicts representations in the Parahippocampal Place Area. We may better understand cortical computations by discovering architectures and training regimes that reproduce the brain's multiple representations of visual information.

Using Psychophysics to Reveal Face Identification Information Processing Mechanisms in a Deep Neural Network

Tian Xu, Oliver Garrod, Robin Ince and Philippe Schyns
Institute of Neuroscience and Psychology, University of Glasgow, UK

Deep convolutional neural networks (CNNs) accurately identify faces from images. However, their underlying information processing remains opaque. To address this, a three-dimensional (3D) generative model controlled the variance of information a 10-layer ResNet architecture learned to identify 2,000 faces. We generated 25M training images by randomly sampling intrinsic (i.e., face morphology, gender, age, expression and ethnicity) and extrinsic (i. e., 3D pose, illumination, scale and 2D translation) face variance factors. At testing, the network generalized identity with 99% accuracy across variance factors. Information mapping psychophysical methods (i.e., Representational Similarity Analysis and Bubbles) revealed, respectively, the ResNet layer that resolves each variance factor and the face features that identify faces. Our explicit control of the generative factors of face information provides a novel framework based on human psychophysics to understand information processing in CNNs and the brain.

Comparing Humans and Deep Neural Networks on Visual Shape Judgments in Cluttered Images

Christina Funke, Thomas Wallis, Judith Borowski, Claudio Michaelis, Alexander Ecker and Matthias Bethge
AG Bethge, University of Tübingen, Germany

There has been ample attention to the recent success of deep neural networks (DNNs) in object recognition tasks on natural images. However, natural images come with a plethora of corollary features that might be used to solve tasks quite differently from humans. Therefore, tasks with simple stimuli are useful to compare humans and DNNs under controlled settings. We aimed to find tasks that are challenging for DNNs but easy for humans. Ongoing work suggests that DNNs rely more on texture cues than on shape, and segmenting shapes from background clutter may be difficult. We propose two tasks to examine this: First, observers discriminated a cluttered display containing a single closed contour from cluttered displays with only open contours against natural image backgrounds. Second, observers detected a novel target symbol in a cluttered image with many symbols. Both tasks demonstrate that the human visual system is still more robust than current machine vision architectures.

Improving DNNs as Models of the Human Ventral Stream: A Better Visual Diet and Recurrent Computations

Tim Kietzmann[1] and Nikolaus Kriegeskorte[2]
[1]MRC Cognition and Brain Sciences Unit, University of Cambridge, UK
[2]Zuckerman Institute, Columbia University, NY, USA

Current deep neural networks (DNNs) are successful at predicting neural responses to visual input despite abstracting from all but the most essential biological features. Since DNN computations are the direct result of architecture, input statistics, and learning objectives, they enable researchers to learn about computations in the brain by investigating how these elements need to be altered to best predict neural responses. Here, we report our recent progress on these frontiers. We show that changing the input statistics to more closely match the human visual diet leads to networks that better match representations in human inferotemporal cortex. Moreover, we jointly model cortical representational dynamics across multiple areas of the human ventral stream by using recurrent DNNs together with a novel time-varying deep learning objective. These experiments demonstrate the limitations of feed-forward models and open a novel window into the dynamic neural mechanisms underlying visual information processing.

Reproducing Decision-Making With Constrained Networks to Understand Deep Neural Networks

Judith Borowski, Wieland Brendel and Matthias Bethge
AG Bethge, University of Tuebingen, Germany

Deep neural networks (DNNs) have surpassed humans on tasks such as object recognition in static images, and their representations provide state-of-the-art prediction of neural activity in visual areas. However, their inner workings remain unclear, limiting their explanatory power. Here, we explore new directions to increase the understanding of DNNs using suitably constrained network architectures that are trained to match intermediate representations of DNNs. As a first constraint, we used scale-restricted networks to show that DNNs trained on object classification primarily act as bag-of-features classifiers as opposed to recognizing global shapes to which humans are sensitive. Secondly, we approximate DNNs with shallow networks to facilitate a direct understanding of the decision-making process. In contrast to widespread visualization methods, the faithfulness of this approach can be directly quantified by suitable similarity measures between the constrained and the original DNN.

Thursday, August 30 – Oral presentations

Eye Movements

Eye meant to Do That: Transsaccadic Perception Depends on Intended Eye-Movements

Martijn Schut, Nathan van der Stoep, Jasper Fabius and Stefan Van der Stigchel
Department of Experimental Psychology, Utrecht University, the Netherlands

We aimed to dissociate the effects of the intended and actual saccade landing point on visual perception using a global effect and an adaptation paradigm. In global effect trials, a saccade target appeared with a distractor, causing saccades to land in between, dissociating actual and intended landing point. Next, we used an adaptation paradigm, causing saccades to land further from the target, by changing the position of the target. Here, no dissociation between intention and landing point is created. In both paradigms, participants indicated the color of the saccade target, which changed slightly during half of the trials, resulting in a mixed percept of the pre- and post-saccadic color. No effect of saccade landing point on color reports was found in the global effect trials, whereas the effect of saccade landing point was present in the adaptation trials. The results show that transsaccadic perception is affected by the intended and not the actual saccade landing point.

Accessing Transsaccadic Memory by Post-Saccadic Blanking

Lukasz Grzeczkowski[1], Jonathan van Leeuwen[2], Artem V. Belopolsky[2] and Heiner Deubel[1]
[1]Department Psychologie, Ludwig-Maximilians-Universität München, Germany
[2]Department of Experimental and Applied Psychology, Vrije Universiteit Amsterdam, the Netherlands

The content and nature of transsaccadic memory (TSM) is still a matter of debate. Brief postsaccadic target blanking was demonstrated to recover TSM and defeat saccadic suppression of displacement. We examined whether blanking would also support TSM of stimulus form. Observers saccaded to a peripheral checkerboard-like stimulus and reported whether an intrasaccadic change had occurred in its upper or lower half. On 50% of the trials, the stimulus was blanked for 200 milliseconds with saccade onset. In a fixation condition, observers kept fixation but the stimulus was displaced from periphery to fixation, mimicking the retinal events of the saccade condition. Results show that stimulus blanking improves transsaccadic change discrimination, with performance being far superior to the retinally equivalent fixation condition. Our findings argue in favor of a remapped perceptual trace that can be accessed only in the blanking condition, when not being overwritten by the salient postsaccadic stimulus.

Sequence-to-Sequence Deep Learning for Eye Movement Classification

Mikhail Startsev, Ioannis Agtzidis and Michael Dorr
Department of Electrical and Computer Engineering, Technical University of Munich, Germany

Models that are based on deep learning have taken over a vast number of areas already. Nevertheless, events in eye-tracking data are still often detected via threshold-based single-sample classification. We developed a method for sequence-to-sequence learning in a multi-class setting, which incorporates one-dimensional convolutional neural networks and bidirectional long short-term memory units. For testing, we use the rich GazeCom data set of naturalistic videos and compare our performance to that of 12 reference models from the literature. Using simple gaze trace features and simultaneously assigning labels in windows of approximately 1 second, our model outperforms the competition in fixation, saccade, and pursuit detection *F*1 score (harmonic mean of precision and recall) by approximately 0.02, 0.03, and 0.06, respectively. We also find that pursuit, being the most difficult eye movement to detect for all the evaluated algorithms, benefits the most from increasing the context size of the analysis.

Where Am Eye Looking? Subjective Gaze Moves Across Space Before Saccade Onset

Meng Fei Ngan, Nina M. Hanning and Heiner Deubel
Allgemeine und Experimentelle Psychologie, Ludwig Maximilians Universität München, Germany

People have an intuitive sense of where their gaze is directed. We asked how subjective gaze shifts when we make a saccade. Participants saccaded towards an endogenously or exogenously cued saccade target (ST). A 25 milliseconds visual or auditory temporal marker was presented at various times around the saccade. Participants indicated the perceived location of their gaze at marker occurrence. Gaze was correctly reported if the marker occurred long before or after the saccade. Remarkably, in the last 250 milliseconds before saccade onset, participants reported

their gaze to be at locations between fixation and ST, and closer to ST, the later the marker was presented. This shows that people have the perception that their eyes are moving towards ST long before saccade onset. Moreover, they have little knowledge about their actual eye position prior to a saccade, they are unaware of the time when they make a saccade and cannot make use of retinal information to correctly indicate objective gaze.

Distribution of Fixations During Natural Reading With Central Field Loss

Éric Castet, Aurélie Calabrèse, Carlos Aguilar and Céline Pocheau
LPC UMR 7290, CNRS – AMU, France

Reading with a central field loss (CFL) relies on eccentric vision. Whether using a preferred retinal locus (PRL) during CFL reading can improve reading performance is still an open issue. To address this question, 23 normally sighted subjects read French sentences with a gaze-contingent artificial scotoma (10°) for 2 hours. Only one word (*N*) of a sentence was visible at a time. All other words were masked by *x* strings. The $N+1$ or $N-1$ word was unmasked (while masking the *N* word) by pressing either the zero or space key on a keyboard. For each subject, a fixation map was created by plotting fixation locations with respect to each word's centre. Reading speed of subjects was regressed on several characteristics of their fixation map. Results notably show that improved reading speed across time correlates with an upward displacement and an enlargement of fixation distributions. We discuss how these new results constrain current theories of the link between PRL and CFL reading.

Systematic Eye Movement Training to Predict the Outcome From Neuroimaging Data at the Initial Stage of Stroke Treatment

Abdulrahman Aloufi, Vanessa Sluming, Fiona Rowe and Georg Meyer
IPHS & ILT, Liverpool University, UK

A better understanding of structural and functional brain changes may optimise post-stroke treatment. The aim of this study is to predict treatment outcome early from functional and structural neuroimaging data in hemianopia patients following visual scanning training. Here, we report on an initial study of 15 healthy participants (aged 20–60 years) who followed systematic visual scanning training for 30 minutes daily, 5 days a week and for 6 consecutive weeks. The training involved eye scanning out to 20° each side of central fixation to locate visual targets in peripheral vision. Participants showed significant improvements in behavioural performance (lower task completion time and fixation number). Significant functional change is seen in visual cortex V3d. Additionally, we show selective activation in Brodmann Area 9 (Superior Frontal Gyrus) for predictive eye movement saccades, but not in reflexive saccades. This area also showed increased functional activation during training.

Eye Movements and Peripheral Vision

(How) Does Pupil Size Affect Detection Performance?

Sebastiaan Mathôt and Yavor Ivanov
Department of Psychology, University of Groningen, the Netherlands

The bigger the pupil, the more light falls onto the retina. In theory, this should improve visual sensitivity, thus facilitating detection of faint stimuli. This may be why pupils dilate in arousing situations, where threats need to be detected quickly. In our experiment, participants detected a faint target that could appear at an unpredictable location. We manipulated pupil size through the color of the visual periphery: Red leads to larger pupils compared to an equiluminant blue, due to differential activation of intrinsically photosensitive retinal ganglion cells, which regulate pupil size. Replicating our previous studies, we found that pupil dilation improves detection within a wide range of pupil sizes. However, very large pupils (>6.5 mm, range: 2–8 mm) unexpectedly impaired detection and seemed to be associated with an increased false-alarm rate. We discuss the complicated (and poorly understood) interactions between pupil size, arousal, and retinal illumination.

Pupillary Response to Paintings of the Sun

Maria Michela Del Viva[1], Serena Castellotti[1], Martina Conti[1] and Claudia Feitosa-Santana[2]
[1]NEUROFARBA, University of Florence, Italy
[2]Albert Einstein Israelite Hospital, Federal University of ABC, Brazil

While the light level is the primary determinant of pupil size, cognitive factors and cortical visual processing can also influence pupillary responses. Photographic pictures of the sun produce pupil constriction independently of luminance and low-level features, suggesting that high-level interpretations of image content also modulate pupil response. Here, we studied this effect in artistic

paintings of scenes containing a visible sun, which require an even higher level of interpretation than photographs. We found that these paintings, despite carrying a decrease in light level across the visual field, can override the pupil dilation normally elicited by a light decrement. On the other end, paintings containing diffuse light, moonlight scenes and inverted and gray-scale versions of the sunlight paintings systematically produced pupil dilation. These results indicate an involvement of high-level visual analysis, such as context and complex image interpretation, on pupil response.

Visual Feature Prediction Before Saccadic Eye Movements

Arvid Herwig and Christian H. Poth
Department of Psychology, Bielefeld University, Germany

The visual system seems to counter saccade-induced changes of visual input by predicting object features across saccades, based on learned associations of pre- and postsaccadic input. Accordingly, peripheral perception should be biased toward predicted foveal input before an imminent saccade. Biases are evoked by the repeated exposure to a consistent trans-saccadic change. Up to now, this was tested only indirectly by adjusting a post-saccadic test stimulus to the memorized presaccadic stimulus. Therefore, it is unclear whether biases arise in pre-saccadic perception or in postsaccadic memory. To clarify, we replaced the postsaccadic adjustment task with a two-alternative forced choice-task: A central stimulus and peripheral stimulus were presented simultaneously before the saccade. Participants had to select the stimulus that was more curved. The results showed biases in the points of subjective equality (PSEs) for objects whose curvature was previously changed, thus providing direct evidence that biases arise predictively in presaccadic perception.

Trans-Saccadic Learning Rapidly Recalibrates Peripheral Size Perception

Matteo Valsecchi[1], Carlos R. Cassanello[2], Arvid Herwig[3], Martin Rolfs[2] and Karl Gegenfurtner[1]
[1]Department of General Psychology, Justus-Liebig-Universität Giessen, Germany
[2]Department of Psychology, Bernstein Center for Computational Neuroscience, Humboldt Universität zu Berlin, Germany
[3]Department of Psychology, Universität Bielefeld, Germany

The repeated exposure to a consistent trans-saccadic change in size produces a corresponding change in the relative perceived size in central and peripheral vision. While it is known that this recalibration can be observed after a few dozen trials, its exact temporal dynamics are unclear. We answer this question using a novel dual task where in each trials observers provided a size estimate, executed a saccade and experienced a post-saccadic stimulus. In multiple experiments, we exposed observers to intra-saccadic size changes that were modulated as a sinusoidal function of trial number as a session progressed. Across experiments, we varied both the frequency of the sinusoidal manipulation and whether the post-saccadic stimulus was presented in every trial. Results point towards a fast learning process, as evidenced by the reduction of its expression after the omission of a single post-saccadic stimulus and by state-equation modeling of the time course of adjusted sizes.

Area Prostriata in the Human Brain

Kyriaki Mikellidou[1], Jan W. Kurzawski[2], Francesca Frijia[3], Domenico Montanaro[3], David Burr[4] and Maria Concetta Morrone[1]
[1]Department of Translational Research on New Technologies in Medicine and Surgery, University of Pisa, Italy
[2]Stella Maris Scientific Institute, Pisa, Italy
[3]Fondazione CNR/Regione Toscana G. Monasterio, Pisa, Italy
[4]Department of Neuroscience, Psychology, Pharmacology and Child Health, University of Florence, Italy

We investigated the functional role of human area prostriata using fMRI population receptive field (pRF) mapping. We calculated pRF maps from blood oxygenation level-dependent (BOLD) responses of 10 healthy volunteers using retinotopic mapping stimuli extending over a wide field of view ($\sim 60^\circ$) and also measured BOLD responses to moderate speed (0.26 c/deg, 38 deg/s) and high speed (0.018 c/deg, 571 deg/s) drifting gratings. We show that human prostriata has a complete representation of the contralateral visual field, clearly distinct from the adjacent area V1 and like the marmoset prostriata, its caudal border with V1 represents the far peripheral visual field with eccentricities decreasing rostrally. Whereas the majority of visual areas show balanced responses to the two drift speeds, prostriata shows a distinct preference for fast motion processing. Its functional properties suggest that it may serve to alert the brain quickly to fast visual events, particularly in the peripheral visual field.

Two-Photon Imaging Evidence for Neurons Specialized in Second-Order Stimulus Processing in Macaque V1

Shuchen Guan[1], Niansheng Ju[2], Shiming Tang[3] and Cong Yu[4]
[1]Peking-Tsinghua Center for Life Sciences, Peking University, China

[2]School of Life Sciences, Peking University, China
[3]School of Life Sciences, McGovern Institute for Brain Research, Peking University, China
[4]Department of Psychology, Peking University, China

Humans perceive luminance-defined first-order stimuli and contrast-defined second-order stimuli. Although psychophysical evidence suggests independent second-order processing, monkey recordings only reveal some first-order neurons also responding to second-order stimuli. Here, we used two-photon imaging to study V1 responses to second-order stimuli in two fixating macaques through an 850×850 mm^2 window at two depths (150 and 300/400 mm). The stimuli were drafting first-/second-order gratings at various spatial frequencies (SFs), orientations and sizes, and presented at $3^\circ/5^\circ$ eccentricity. Among $>$3k SF/orient tuned neurons, 15% only respond to second-order stimuli, 76% only to first-order gratings, and 9% to both. Compared to first-order neurons, second-order neurons show similar SF/orient tuning and Rmax but weaker direction selectivity and surround suppression. These results demonstrate the existence of V1 neurons specialized in processing of second-order SF and orientation, although processing of second-order motion may occur at a later stage.

Research Methods and Computational Models

Absorption Efficiency of Cones Is Considerably Affected With Healthy Aging

Daphne Silvestre, Angelo Arleo and Remy Allard
Department of Visual Information, Institut de la Vision, France

The specific underlying cause of age-related contrast sensitivity losses is still elusive. The current psychophysical study used a recently elaborated noise paradigm to estimate the optical factors of the eye, absorption rate of photons by cones, neural noise and processing efficiency. To estimate the impact of these factors on contrast sensitivity, contrast thresholds were measured over a wide range of spatial frequencies and different luminance intensities for 20 young and 20 healthy older adults. All these factors were slightly, but significantly, affected by healthy aging except the absorption rate which considerably dropped suggesting that older adults absorbed about 3.8 times less photons. Given that the number of cones does not drastically drop with healthy aging, and that the pupil size and the yellowing of the lens were controlled for, we conclude that the absorption efficiency of cones is considerably affected with healthy aging.

Fast Concurrent Processing of Object Shape and Category in Posterior MEG Sensors

Paolo Papale[1], Monica Betta[1], Francesca Setti[1], Giulia Malfatti[2], Pietro Pietrini[1], Emiliano Ricciardi[1], Luca Turella[2] and Andrea Leo[1]
[1]MoMiLab, IMT School for Advanced Studies Lucca, Italy
[2]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy

Features relevant to biological vision span from edges and lines, to object-based attributes, as shape and category. However, the relative impact of these features in the emergence of coherent percepts is not known yet. Moreover, these features are often interrelated—for example, faces and places have specific spectral signatures. Here, by employing a model-based approach, we investigated the temporal dynamics of object processing in a MEG study. Taking collinearity into account, we observed fast (100–150 milliseconds) processing of low-level features (contrast and spatial frequencies), shape (medial-axis) and category within the same spatial patterns of sensors. This study confirms previous neuroimaging evidence showing spatial associations between category and shape processing. Overall, the observed spatiotemporal patterns may result from an integrated perceptual mechanism, rather than from a strict feedforward hierarchy, suggesting also a role of shape in the refinement of categorical matching.

The Relation Between Pleasure and Beauty

Aenne Brielmann and Denis Pelli
Department of Psychology and Neural Science, New York University, NY, USA

Philosophers claim that beauty is a kind of pleasure. Here, we empirically test a mathematical model that describes the beauty–pleasure relation. Participants ($N = 18$) continuously rate pleasure while viewing images for 5 seconds and for another 10 seconds after. At the end of each trial, they rate their overall feeling of beauty on a 4-point scale. First, we summarize continuous pleasure ratings with a one-free-parameter model. Second, the joint distribution of pleasure and beauty is well modeled ($r = .72 \pm .2$) as a bivariate Gaussian where beauty means are a linear transformation of pleasure means. For each observer, the relation between beauty and pleasure is constant across stimulus types. Thus, our model fits demonstrate that the relation between beauty and pleasure is stable across experience. Yet, (co-)variances differ widely between observers and stimuli, showing that beauty and pleasure cannot be equated.

A Recursive Bayesian Updating Scheme to Model the Effect of Prediction on Individuation

Huseyin Boyaci[1] and Buse M. Urgen[2]
[1]Department of Psychology, Bilkent University, Turkey
[2]National Magnetic Resonance Research Center and A.S. Brain Research Center, Bilkent University, Turkey

We present a recursive Bayesian updating scheme in which posterior of an iteration is used as the prior of the next, to model empirical results of an individuation task within the framework of predictive computation. In the experiment, participants were asked to report the location of a briefly presented image. In each trial, task-irrelevant cues (75% valid) provided information about the prior probability of the upcoming image category. The duration of the image presentation was determined using an adaptive staircase procedure in a two-alternative forced choice task, and the thresholds were estimated in congruent and incongruent trials. Our results showed that thresholds were higher in incongruent trials than in congruent trials, confirming that prediction has an effect on individuation. Our Bayesian scheme was able to successfully capture the pattern observed in human observers, suggesting that schemes with iterative priors may lead to better models of human behavior than approaches using static priors.

Are We Fooling Ourselves When Comparing Mean Correct RTs, and Error Percentages?

Sven Panis and Thomas Schmidt
Department of Experimental Psychology, University of Kaiserslautern, Germany

Why do we take so much care to obtain high-resolution RT data when we collapse all the temporal information by calculating a single, mean (correct) RT? More and more research findings show that RT variance is not just noise, and that the mean RT is not more informative than any other time point at which responses occur. Furthermore, the dynamic systems approach to cognition states that cognition will involve transitions between different, temporarily stable sensory and motor states as time passes on. Therefore, the optimal data-analytic approach for RT and other time-to-event data is an intuitive longitudinal technique known as discrete time Event History Analysis (a.k.a. survival, hazard, duration, transition, and failure-time analysis). By putting the passage of time in the center of the analysis, subjective data trimming decisions become dispensable, and one can study how the effect of an experimental manipulation on response occurrence and accuracy changes across different time scales.

How to Control for Confounds in Decoding Analyses of Neuroimaging Data

Lukas Snoek, Steven Miletić and H. Steven Scholte
Department of Psychology, University of Amsterdam, the Netherlands

Over the past decade, "decoding" analyses have become a popular method in neuroimaging research. However, decoding analyses are notoriously hard to interpret in terms of the source(s) of variance in the data that the model uses to generate predictions, which becomes especially problematic when facing confounds. Here, we evaluate two methods for controlling for confounds: counterbalancing and confound regression. We find that counterbalancing leads to positive bias because it tends to "reject" samples that lie close to the decision boundary, suggesting circularity in the analysis. Also, we find that confound regression as it is traditionally used is strongly negatively biased (i.e., leads to significant below-chance accuracy), which we explain by comparing it to the sampling distribution of the correlation coefficient. Importantly, we show that proper cross-validation of the confound regression procedure yields plausible, interpretable, and unbiased estimates of model performance.

Illusions and Object Perception

The Illusion of Perceptual Stability Through Serial Dependence

Mauro Manassi and David Whitney
Department of Psychology, UC Berkeley, CA, USA

Perception can be strongly biased toward previously seen stimuli. Such serial dependencies may enhance the apparent stability of objects by smoothing visual representations over time. Here, we introduce a new visual illusion, which shows direct evidence of how serial dependence promotes the stable appearance of ever-changing objects. In a single-trial, single-shot experiment, 300 observers attended to a 30-s video with a face ageing from young to old (or vice versa). At the end of the video, after a gap, observers reported the age of a visible test face that was identical to the last face in the video. The rated age of the test face was strongly biased towards the earlier faces seen in the video. Because of serial dependence, the identity of the face is continuously merged over time and, as a result, observers perceive a slower age change. Our illusion provides the first direct demonstration of the causal link between serial dependence and perceptual stability.

Sequence Irregularity Oppositely Influence Spatial and Temporal Estimates

Min Li[1], Ulrik Beierholm[2] and Massimiliano Di Luca[1]
[1]School of Psychology, University of Birmingham, UK
[2]Department of Psychology, Durham University, UK

To investigate whether regularity of sequence can create interaction between spatial and temporal estimates, current study uses sequence presented in regular spatiotemporal intervals, except for the final stimulus that could appear with a spatiotemporal irregularity. In experiment 1, we asked subjects to report whether the last stimulus appeared perturbed in time and found that final stimuli presented further away in space were reported to appear later in time. In Experiment 2, the subjects had to report spatial perturbations. We found final stimuli presented earlier in time had to be presented close in space as if they were perceived further away. The opposite outcomes revealed the role of attention: When time was attended, the illusion of time dilation was induced as if space and time were positively correlated. When space was attended, the subjects adopted a constant-velocity strategy compensating time mismatch with spatial alignment.

When the Brain Fools Your Eyes: Pupillary Response in Motion-Induced Blindness

Dina Devyatko[1], Ronen Hershman[2], Michael Wagner[3,4], Ruth Kimchi[1] and Avishai Henik[5]
[1]Institute of Information Processing and Decision Making, University of Haifa, Israel
[2]Department of Cognitive and Brain Sciences, Ben-Gurion University of the Negev, Israel
[3]Department of Industrial Engineering, Ariel University, Israel
[4]Department of Psychology, Ariel University, Israel
[5]Department of Psychology, Ben-Gurion University of the Negev, Israel

Pupil size was shown to reflect changes in the perceptual state of a physically unchanged dot for which illusory disappearance occurred due to motion-induced blindness. We examined whether change of pupil size in response to illusory disappearance would be different for white and black dots. According to the pupillary light reflex, presenting a white dot should lead to pupil constriction, while presenting a black dot should cause pupil dilation. The opposite pupillary responses are anticipated for physical disappearance of these dots, but what about illusory disappearances? When we presented white or black dots on a grey rotating mask, we found illusory disappearance of the dots triggered pupillary responses similar to those predicted by the light reflex. Namely, disappearance of a white dot led to pupil constriction and disappearance of a black dot led to pupil dilation, suggesting higher level influences on pupillary response.

The Ebbinghaus Size Illusion Depends More on the Retinal Than Perceived Size of Surrounding Stimuli

Saki Takao[1], Colin Clifford[2] and Katsumi Watanabe[1]
[1]Faculty of Science and Engineering, Waseda University, Japan
[2]School of Psychology, UNSW Sydney, Australia

A stimulus surrounded by smaller/larger stimuli appears larger/smaller (Ebbinghaus illusion). We examined whether the Ebbinghaus illusion would depend on the retinal or perceived size of the surrounding stimuli. For this, we used the flash-lag effect, where a flashed stimulus perceptually lags changing stimuli. Two sets of four surrounding disks changed their size smoothly: one with larger disks shrinking and the other with small disks expanding. Two identical central disks were presented briefly at various timings relative to the moment when the surrounding disks were identical (coincidence time). Observers reported the two central disks being in equal size when they appeared slightly (mean = 17 milliseconds; $SE = 22.5$ milliseconds) before the coincidence time. This was significantly smaller than the flash-lag effect measured in a subsequent experiment (mean = 228 milliseconds; $SE = 77.5$ milliseconds). These results suggest that the Ebbinghaus illusion depends more on the retinal than perceived size of the surrounding stimuli.

Differential fMRI Responses to Material Motion Compared to Other Motion Types

Alexandra Schmid[1], Huseyin Boyaci[2] and Katja Doerschner[3,4]
[1]Department of Psychology, Justus Liebig University Giessen, Germany
[2]Department of Psychology, Bilkent University, Turkey
[3]Justus Liebig University Giessen, Germany
[4]Bilkent University, Turkey

There is growing research interest in where or whether materials are uniquely represented in the brain. Motion is particularly important for the perception of non-rigid materials, but its neural basis remains unexplored. Using functional magnetic resonance imaging (fMRI), we investigated whether brain regions respond differentially to

material motion versus other motions. Stimuli were novel point-light animations that induce vivid percepts of various materials in motion, for example, flapping cloth, liquid waves, wobbling jelly. Control stimuli were scrambled motion and rigid three-dimensional rotating dots. Using a block design, we contrasted fMRI responses to different motion types. We found differential responses for material motion in several areas including the middle temporal complex, superior temporal as well as parietal regions. These results are a first important step in mapping out the cortical architecture and dynamics in material-related motion processing.

3D Vision, Depth, and Stereo

Human 3D Shape Similarity

Guido Maiello, Yaniv Morgenstern, Filipp Schmidt and Roland Fleming
Department of Experimental Psychology, Justus-Liebig University Gießen, Germany

Humans have an intuitive sense of whether distinct three-dimensional (3D) shapes are similar or not. For example, a pot appears more similar to a cup than to the plant it contains. The ability to judge the similarity of 3D shapes is likely a key component of human object recognition and classification. Yet which features we use to make these judgements is unclear. Global shape features such as sphericity or number of limbs may help us differentiate a starfish from a sea urchin. Local shape features such as surface curvature may guide us towards a spoon instead of a knife. We had 12 human observers rate the pairwise similarity of a set of randomly generated unfamiliar objects. A simple similarity metric based on global and local 3D object geometry captures a significant portion of the variance in similarity ratings ($r^2 = .40$; 95% CI [0.29, 0.48]). We employ these findings to devise a set of 3D shape descriptors capable of predicting human shape similarity judgements directly from the visual input.

Retinal-Conjugate Surfaces: The Blur Horopter

Agostino Gibaldi[1], Vivek Labhishetty[1], Larry N. Thibos[2] and Martin S. Banks[1]
[1]School of Optometry, UC Berkeley, CA, USA
[2]School of Optometry, Indiana University, IN, USA

When we fixate an object, the image of that object is brought to sharp focus on the fovea due to the eye's accommodation. Other objects in the periphery may be farther or nearer than best focus on those parts of the retina. Using wavefront-aberration data from 15 emmetropic eyes in the central 30° of the visual field, we determined the shape of the surface of best focus in the world as the eye accommodates to different distances. The resulting surface – the retinal conjugate – is consistently pitched top-back and rotated slightly nasal-back. We show that those effects are consistent with the statistics of the natural environment for people engaged in everyday tasks. The surface is also near the empirical horopter (the position in the world where stereopsis is most precise) at different viewing distances. We conclude the retinal-conjugate surface and horopter conform to habitual environmental statistics.

Reevaluating Vergence as a Distance Cue

Paul Linton
Centre for Applied Vision Research, City, University of London, UK

Vergence is regarded as one of the most reliable sources of egocentric distance information in reaching space. However, studies of distance from vergence typically fail to control for (a) initial diplopia in the stimulus and (b) the changing retinal image during convergence. I present the results from two experiments that demonstrate that once these factors are controlled for the gain from vergence drops from 0.86 to 0.16, even when (as in the second experiment) accommodation cues are also present. These results have three important implications: First, they lead us to question whether vergence is used to scale the size and distance of objects. Second, they lead us to question whether vergence is used in conjunction with binocular disparity to scale the depth of the scene. Third, if all our distance cues are either relative (diplopia, relative size) or merely cognitive (familiar size), they lead us to question whether the visual system extracts any information about absolute scale.

Parallel Lines Sometimes Diverge: A New Perspective Illusion

Brian Rogers[1] and Alla Cherniavskaia[2]
[1]Department of Experimental Psychology, University of Oxford, UK
[2]Department of Psychology, St Petersburg State University, Russia

Imagine a photo of a long corridor with a superimposed line that is parallel to the boundary between one wall and the floor. The line no longer appears parallel but instead appears to diverge towards the end of the corridor. Observers adjusted the rotation of the superimposed line until it appeared parallel to the wall-floor boundary. The role of perspective was tested by removing the texture on the floor, walls or ceiling and the role of disparities

using stereo images of the corridor. Results were expressed in terms of the average constancy: 0% if the setting was parallel to the boundary in the picture plane and 100% when parallel to the boundary in the three-dimensional (3D) scene. Constancy was just ~8% when the corridor was defined only by lines between the walls and floor/ceiling, 55% for 2D photos and >70% for stereo images. The illusion size is related to the extent the corridor is seen as a 3D scene, and hence, it provides a new way of assessing the strengths of different sources of 3D information.

Experiencing 3D: Identifying the Cortical Substrates of the Qualitative Impression of Stereopsis With fMRI

Dhanraj Vishwanath[1], Makoto Uji[1], Ian Cavin[2] and Angelika Lingnau[3]
[1]School of Psychology & Neuroscience, University of St. Andrews, UK
[2]Clinical Radiology, NHS Tayside, UK
[3]Department of Psychology, Royal Holloway University of London, UK

Three-dimensional (3D) structure can be perceived in pictures, but viewing real scenes or stereoscopic images with both eyes gives a vivid qualitative impression of tangibility and real separation in depth. This impression (stereopsis) is typically explained as a byproduct of depth derived from binocular disparities. However, the same impression can also be induced under monocular viewing of single pictures through an aperture. Previous neuroimaging studies have focused primarily on identifying neural substrates involved in deriving depth from disparity. Here, we conducted the first functional magnetic resonance imaging (fMRI) study to identify substrates underlying the subjective experience of stereopsis. For contrasts aimed at isolating stereopsis, fixed effects general linear model analysis demonstrated a selective recruitment of posterior parietal regions, but not ventral or occipital regions. Furthermore, the recruited regions for monocular and binocular stereopsis overlapped suggesting they are similar phenomena with shared neural substrates.

Implicit and Explicit Assessment of Environmental Stability Modulates Visually Evoked Postural Responses in VR

Georg Meyer[1], Iain Cant[2], Mark White[3] and Natalia Cooper[4]
[1]IPHS, University of Liverpool, UK
[2]Virtual Engineering Centre, Liverpool University, UK
[3]Department of Mechanical, Materials & Aerospace Engineering, Liverpool University, UK
[4]Construction Research Centre, National Research Council, Ottawa, Canada

Visually evoked postural responses (VEPR) occur when we counteract perceived self-motion (vection). There is increasing evidence for cortical involvement in postural control. VEPR, for example, are specific to the environmental configuration and are different in 'virtual' environments than in 'reality'. We measured VEPR in a virtual reality (VR) environment. Experiment 1 tests the effect of accommodation-vergence conflict (AVC) conflict. We show significant VEPR when the motion stimulus is projected without AVC. When projecting motion 2 m behind the focal plane (AVC condition), no significant VEPR are seen. Experiment 2 tests whether cognitive assessment of the likely stability of visual reference points affect VEPR. We show that the perceived positional stability of environmental components modulate postural responses. We conclude that implicit and explicit assessment of the stability and reality of postural anchors in VR environments modulate VEPR and propose VR design guidelines.

Crowding

Using the Neurorobotics Platform to Explain Global Processing in Visual Crowding

Alban Bornet[1], Alexander Kroner[2], Jacques Kaiser[3], Fedor Scholz[3], Gregory Francis[4] and Michael H. Herzog[1]
[1]BMI, EPFL, Switzerland
[2]Department of Cognitive Neuroscience, Faculty of Psychology and Neuroscience, Maastricht University, the Netherlands
[3]Department of Intelligent Systems and Production Engineering, FZI Research Center, Germany
[4]Department of Psychological Sciences, Purdue University, IN, USA

The Neurorobotics Platform of the Human Brain Project hosts many different large-scale models that can easily be connected with each other. Here, we linked a deep neural network for saliency computation to a spiking cortical model for visual segmentation (the Laminart model) to investigate global effects in visual crowding. Global effects are observed, in a Vernier discrimination task, where the target is flanked by one to seven squares spanning up to 17° of the peripheral visual field. Contrary to predictions of most models, crowding is lower as more squares flank the target. In the simulation, the saliency model uses fast bottom-up information to bias the segmentation processes of the Laminart model towards specific parts of the visual stimulus. Simulations of the model with the same stimuli as

in empirical studies produce essentially the same behavior as human observers.

Too Good to be Crowded: A Peculiar Case of Weak Crowding With High Target-Flanker Similarity

Natalia Melnik[1], Daniel Coates[2] and Bilge Sayim[1,3]
[1]Institute of Psychology, University of Bern, Switzerland
[2]College of Optometry, University of Houston, TX, USA
[3]University of Lille, CNRS, France

Peripheral vision is strongly limited by crowding, the phenomenon in which target identification is hindered by the presence of flankers. One of the hallmarks of crowding is that flankers similar to the target usually crowd more than flankers that differ. Here, we show a peculiar exception to this rule. Participants judged the configuration of two target chevrons (Up-Up, Down-Down, Diamond, X) among Diamond and X flankers. Surprisingly, in the Diamond-flanker condition, Diamond target configurations were identified better than Xs. However, Diamond targets were not subjectively judged to stand out more from the flankers. There was no difference between Diamonds and Xs in the X-flanker condition. Our results show that in contrast to previous findings, target-flanker similarity does not always predict performance. We suggest that the degree to which a target has good Gestalt properties and the regularity of the entire stimulus play a vital role in the ability to identify flanked targets.

Visual Crowding and Focal Attention: Psychophysical and Neuropsychological Evidence of a Link

Roberta Daini[1], Andrea Albonico[2], Lisa Saskia Arduino[3], Emanuela Bricolo[1], Eleonora Frasson[1], Manuela Malaspina[2] and Marialuisa Martelli[4]
[1]Department of Psychology, Università di Milano – Bicocca, Italy
[2]Department of Ophthalmology and Visual Sciences, University of British Columbia, Canada
[3]Department of Human Sciences, LUMSA Università, Italy
[4]Department of Psychology, Università di Roma La Sapienza, Italy

Focal attention refers to the adjustment of the attentional window size and can be modulated by presenting a cue of different sizes before the target appearance. To verify if focal attention counteracts crowding phenomenon in central vision, we requested to healthy participants to discriminate the orientation of a 'T', close to acuity threshold, presented with left and right 'H' flankers, as a function of target-flanker distance. Moreover, we assessed right brain-damaged patients with reading difficulties by a paradigm of focal attention, words reading and crowding tests. We found that an optimal cue of focal attention reduces crowding in central vision in healthy participants and that crowding is enhanced and induce substitution errors in words reading of patients with attentional deficits. We call this condition 'crowding dyslexia' and suggest that it might depend on the focal attention resolution needed to define the optimal field of integration for letter identification.

When Uncrowding of Parts Interferes With Identifying Wholes in Peripheral Word Recognition

Koen Rummens[1] and Bilge Sayim[1,2]
[1]Institute of Psychology, University of Bern, Switzerland
[2]University of Lille, CNRS, France

Word recognition is limited by crowding, the deleterious influence of nearby objects (flankers) on target identification. Crowding generally weakens with decreasing target-flanker similarity on a given dimension (e.g., color). Here, we investigated if uncrowding of (non)syllabic word parts by color, luminance, and combined color-luminance differences helps or hinders peripheral word recognition. In four experiments, observers verbally reported a word presented briefly at 8° in the lower visual field. The words were uniform (e.g., all letters black), congruent (e.g., alternating black and white syllables), or incongruent (e.g., alternating black and white nonsyllabic word parts). Words were recognized faster in the uniform compared to all other conditions. Our results show that uncrowding of syllabic and nonsyllabic word parts both interfered with peripheral word recognition. We suggest that advantages of the uncrowding of parts entail a cost when identifying wholes.

Is Temporal Crowding Merely Long-Lasting Masking?

Yaffa Yeshurun and Shira Tkacz-Domb
Department of Psychology, University of Haifa, Israel

Temporal crowding refers to impaired target identification when other items precede and succeed it. Previously, we showed such impairment even when interitems **stimulus-onset asynchronies** (SOAs) were longer than 400 milliseconds. Here, we used a continuous orientation report task to examine the processes underling temporal crowding. Observers viewed a sequence of three randomly oriented items with varying SOAs (175–475 milliseconds) and reproduced the target's (the middle item) orientation. We measured the difference between original and reported

orientation. Unlike classical masking, with which SOA mainly affects guessing rate, we found a significant effect of SOA on encoding precision and substitution rate, but not on guessing rate. This suggests that temporal crowding is not merely 'particularly long' masking, but rather involves different processes. In addition, unlike spatial crowding, with which reducing target-distractors similarity mainly affected guessing rate, we found that reducing similarity mainly affected substitution rate.

Seven Myths on Crowding

Hans Strasburger
Institute of Medical Psychology, University of München, Germany

Crowding research has become a hotbed of vision research and some fundamentals are now widely agreed upon. You would agree with the following statements – wouldn't you? (a) Bouma's Law can be sensibly stated as saying that 'critical distance for crowding is about half the target's eccentricity'. (b) Crowding is a peripheral phenomenon. (c) Crowding increases drastically with eccentricity (as does the minimal angle of resolution, MAR). (d) Crowding asymmetry: For the nasal-temporal asymmetry of crowding, Bouma's paper is the one to cite. (e) The more peripheral flanker is the more important in crowding. (f) Critical crowding distance corresponds to a constant cortical distance in V1. (g) Except for Bouma, serious crowding research pretty much started in the noughties. I propose the answer is 'no!' to all these questions. So should we care? I think we should, before we write the textbooks for the next generation.

Art and Scene Perception

Both Artworks and Computer-Generated Images With Equivalent Physical Properties Evoke Similar Aesthetic Subjective Judgements

Vicente Estrada[1], Markus Müller[2], Anjan Chatterjee[3] and Stacy Humphries[3]
[1]Department of Psychology, UNSW, Australia
[2]Department of Complex Systems, UAEM, USA
[3]Department of Cognitive Neuroscience, University of Pennsylvania, PA, USA

Complexity on artworks seems to play a very important role on the cognitive effect triggered by seeing them. The question that arises is this: What is an objective measure of complexity in aesthetic expressions? Chatterjee and cowokers have found that certain physical features (scores from Hue, Saturation & Value [HSV] color space) are correlated to subjective judgements of complexity in abstract paintings. Moreover, it has been proven that modulation of HSV scores can influence perception of naturalness and warmness when diverse landscapes were exposed. In this project, we presented HSV modulations from Pollock and Mondrian's paintings and found that Value scores mediate perception of complexity, interestingness and locomotion. Finally, perception of beauty was dependent on all three chromatic components.

The Importance of the Point de Vue – Looking on the Ground and Elsewhere

Dirk Junker and Christian Nollen
Agrarwissenschaften und Landschaftsarchitektur, Hochschule Osnabrück, Germany

Based on the study Point de Vue, we can assume that mobile eye tracking is a proper method to be an invisible companion and to study the natural behavior of visitors in a landscape architectural context. Before that, landscape architecture gained knowledge by use of verbal data collection methods or through observations, but now mobile eye tracking proved its capability to be a profound method even for long experiments up to 2 hours in real-world environments. Research areas were historical grand gardens and parks as spots of individual recreation, culture-historical encounters and common experiences. Research object was the perception of Points de Vue against the background of the individual interaction with the scenery. Results show an ambivalent distribution of attention and primarily expose the variety between attention on 'important' focal points and trivia. Only by mobile eye tracking, it is possible to study the rhythm and the necessary coexistence of these apparent antagonism.

Maps of Visual Importance

Xi Wang[1], Kenneth Holmqvist[2] and Marc Alexa[1]
[1]Department of Computer Science and Electrical Engineering, TU Berlin, Germany
[2]Institute for Psychology, Regensburg University, Germany

It has been shown that not all fixated locations in a scene are encoded in visual memory. We propose a new way to probe experimentally whether the scene content corresponding to a fixation was considered important by the observer. Our protocol is based on findings from mental imagery showing that fixation locations are reenacted during recall. We track observers' eye movements during stimulus presentation, and subsequently, observers are asked to recall the visual content while looking at a neutral background. The tracked gaze locations from the two

conditions are aligned using an novel elastic matching algorithm. Motivated by the hypothesis that visual content is recalled only if it has been encoded, we filter fixations from the presentation phase based on fixation locations from recall. The resulting density maps encode fixated scene elements that observers remembered, indicating importance of scene elements. We find that these maps contain top-down rather than bottom-up features.

Anchor Objects Predict Search Performance in Real-World Scenes

Melissa L.-H. Vo[1], Sage Boettcher[2] and Dejan Draschkow[1]
[1]Department of Psychology, Goethe University Frankfurt, Germany
[2]Department of Experimental Psychology, University of Oxford, UK

Scene grammar plays an important role in real-world search. We propose that some objects function as anchors, carrying strong spatial predictions about other objects within the scene (e.g., a stove anchors a pot). To test this, we manipulated the presence of such anchors in eye tracking experiments and found that anchor objects can guide visual search leading to faster reaction times (RTs), less scene coverage, and less time between fixating the anchor and the target. Further, to quantify the spatial relationship between objects in different scene categories, we extracted the spatial locations of objects from an image database. Inspired by graph theory, we captured the relationship of objects as a set of nodes connected by edges of varying weights. We tested the weights' behavioral relevance by correlating them with RTs. Results show that RTs decrease as weights increase. We take this as evidence that anchors affect and predict single trial search performance for other objects in naturalistic scenes.

Set Summary Perception, Outlier Pop Out, and Categorization: A Common Underlying Computation?

Shaul Hochstein[1], Noam Khayat[2], Marina Pavlovskaya[3], Yoram Bonneh[4] and Nachum Soroker[3]
[1]ELSC Safra Center for Brain Research & Life Sciences Institute, Hebrew University, Israel
[2]Life Sciences Institute, Hebrew University, Israel
[3]Lowenstein Rehabilitation Center and Tel Aviv University, Israel
[4]Department of Optometry and Visual Science, Bar-Ilan University, Israel

Recent research on set statistics perception found observers, presented briefly with element sets, report set feature means, though unaware of individual element values (low-/high-level features; circle size, facial expression). How can one compute mean values without knowing individuals? We extend these findings shedding light on this conundrum. We find set mean computation performed on-the-fly, automatically, implicitly, affecting unrelated tasks. Observers also identify set outliers, indicating they perceive stimulus set ranges. Range perception, too, is automatic, implicit, and on-the-fly. In purposely designed parallel studies, we find similar characteristics for set and category perception (category prototype/boundary resemble set mean/range), suggesting categorization and set perception may share computational elements. We analyze a population code computational procedure, encompassing set and categorization features, avoiding classic debates of category prototype versus boundary. This work is supported by Israel Science Foundation.

Visual Search and Bistable Perception

Effect of Conscious Awareness of Distractors on Reaction Times to Seen Targets

Matilda Cederblad, Aleksandar Visokomogilski, Søren K. Andersen, Mary-Joan MacLeod and Arash Sahraie
Department of Psychology, University of Aberdeen, UK

Manual reaction times (RT) to the onset of visual targets is faster if multiple targets are presented compared to target singletons. This facilitation of RTs to multiple targets is called the redundant target effect (RTE), and it is attributed to speeded responses due to sampling from RT distributions (Race model) or an interaction between stimuli (Co-activation model). However, the role of awareness in modulating RTE in healthy observers is unclear. Using Continuous Flash Suppression, we investigated the effect awareness of a suppressed target on the RT to the onset of an unmasked singleton. Over multiple studies we found that (a) the RTs to an unmasked target were faster when the participant reported awareness of the distractor, (b) awareness is related to the target/distractor spatial locations, and (c) there was an active inhibition of RTs when no visual awareness of distractor was reported. The findings cannot be accounted fully by either the Race or Co-activation models.

Ultrarapid Detection of Animal Visual Warning Signals

Olivier Penacchio and Julie M. Harris
School of Psychology and Neurosciences, University of St Andrews, Scotland

Visual warning signals (WS) form a widespread class of animal signals whereby distinctive colourations, thought to be particularly conspicuous, inform would-be predators that they are well-defended and unprofitable. We explored whether WS are particularly conspicuous for humans in a fast detection experiment. Pairs of images of natural scenes normalised for contrast, only one of which pictured an animal, were flashed on in the left and right hemifields for 20 milliseconds. Observers had to report on which side an animal had appeared without being aware that the target category, animal, was divided into WS and control. Interestingly, WS were distinctive amongst animal and boosted performance: detection time was significantly shorter (30 milliseconds, 428 vs. 457 milliseconds) and performance more accurate (95.5% vs. 90%) for animals with WS than for control. Low-level image statistics analysis showed that this differential response is driven by the fragmentation of the distribution of contrast energy.

The Preview Benefit in Easy and Difficult Color X Form Search

Günter Meinhardt, Sophie Lukes and Malte Persike
Department of Psychology, University of Mainz, Germany

Showing distracters before the remainder items add to the display facilitates visual search. In seminal studies on the preview benefit (PB), it was proposed that a visual marking mechanism actively encodes previewed distracter locations to inhibit them at search. Recently, it was reported that the PB was diminished in color x form search, but not in form search with uniform color items. This suggests active color processing of the preview items in color x form search. Here, we varied the efficiency of form search from near efficient to highly inefficient by varying target-distracter form similarity. For near efficient form search, the PB was disrupted in color x form search, but intact in form search. For highly inefficient form search the effect reversed, and the PB was intact in color x form search, but diminished in form search. This suggests that active color processing supports spatio-temporal segregation into old and new items only when bottom-up form saliency is weak.

The Hyperactivity of the Magnocellular System and Cognitive Impairment in Patients With the First-Episode of Schizophrenia

Elena Isaeva[1], Irina Shoshina[2], Yulia Simon[1], Yulianna Mukhitova[1], Alexander KhaǹKo[1] and Oleg Limankin[1]
[1]Department of General and Clinical Psychology, Pavlov First Saint Petersburg State Medical University, Russia
[2]Laboratory of Physiology of Vision, Pavlov Institute of Physiology, Russian Academy of Sciences, Russia

We studied the features of contrast sensivity, the visual perception, and cognitive functions in patients with first-episode of schizophrenia. It was found that patients with first-episode of schizophrenia are characterized by increased contrast sensitivity in the range of low spatial frequency. At the same time, contrast sensitivity in the range of medium and high spatial frequencies is reduced. The obtained data are considered as the evidence of the mismatch in the functioning of magnocellular and parvocellular systems. We found relationship of the impairment of cognitive control and selectivity of attention with the hyperactivation of a magnocellular system. The hyperactivation of the magnocellular system is the impairment of the selective attention, an excessive amount of information enters the brain, which leads to a dysfunction of the integrity perception, disorganization of thinking, and psychotic disorganization. This work is supported by the RFBR (18-013-01245).

Pupillometry Reveals Perceptual Differences That Are Tightly Linked to Autistic Traits in Typical Adults

Paola Binda[1], Marco Turi[2] and David Burr[3]
[1]Department of Translational Research and New Technologies in Medicine and Surgery, Università di Pisa, Italy
[2]Fondazione Stella Maris Mediterraneo, Italy
[3]Department of Neuroscience, Psychology, Pharmacology and Child Health, Università di Firenze, Italy

We measured pupil size in 50 typical adults viewing a structure-from-motion stimulus: a bistable-rotating cylinder of constant luminance, made from left-moving white and right-moving black dots. As attention can modulate pupil size, attending locally to the front surface should cause pupil constrictions or dilations depending on whether the front surface is made of white or black dots; however, attending globally to the whole cylinder should produce no systematic pupil modulations. In our subjects, reversal-linked pupil modulations varied continuously between these two extremes. Crucially, modulation amplitudes were highly correlated ($r = .7$, $p = .00001$) with scores on the Autism-Spectrum Quotient (AQ), a personality test

known to associate with local-global perception (higher AQ, larger pupil modulations). This is the first evidence that pupillometry reliably tracks interindividual differences in perceptual styles, objectively and without interfering with spontaneous perceptual strategies.

Can I Trust in What I See? EEG Evidence for Reliability Estimations of Perceptual Outcomes

Jürgen Kornmeier[1], Ellen Joos[2], Michael Bach[3] and Ludger Tebartz van Elst[4]
[1]Department of Perception and Cognition, Institute for Frontier Areas of Psychology and Mental Health, Germany
[2]Department of Cognitive Neuropsychology and Pathophysiology of Schizophrenia, University of Strasbourg, France
[3]Section Visual Function, Eye Center University of Freiburg, Germany
[4]Department of Psychiatry and Psychotherapy, Medical Center, University of Freiburg, Germany

During observation of an ambiguous figure, perception becomes unstable and alternates between different interpretations. Tiny low-level changes can disambiguate an ambiguous figure and stabilize its percept. We compared event-related potentials (ERPs) evoked by ambiguous stimuli and disambiguated stimulus variants across different visual categories (geometry, motion) and complexity levels (up to emotional face expressions). Disambiguated stimulus variants cause stable percepts and evoke much larger amplitudes of two positive ERP components than ambiguous stimuli ($d > 1$). This pattern of results is highly consistent across visual categories and complexity levels. The generality of our findings across categories and complexity levels points to higher level/cognitive mechanisms: Given a priori incomplete, noisy, and ambiguous sensory input, we postulate a high-level Bayesian inference unit that evaluates the reliability of perceptual processing results. Large ERP amplitudes would reflect high perceptual reliability.

Multisensory and Decision-Making

Metacognitive Control of Sensory Evidence Accumulation

Tarryn Balsdon, Valentin Wyart and Pascal Mamassian
Département d'études cognitives, École normale supérieure, PSL Research University, CNRS, France

Perceptual decisions are accompanied by a feeling of confidence as to whether the decision was correct. We asked if this metacognitive information is used to stop collecting evidence for a decision in natural sensory environments. Observers were progressively shown evidence for an orientation discrimination decision and were asked to stop when they reached a certain level of confidence. In a later session, trials were replayed with either more or less evidence. On those trials, observers were more efficient in their metacognitive judgements. Using computational models, we then quantified the contribution of sensory evidence to perceptual decisions and confidence judgements, and the relationship of sub-optimalities in each. These results highlight the role of confidence in metacognitive control – the selection of sensory evidence – rather than simply metacognitive monitoring – the evaluation of perceptual correctness.

The Influence of Multitasking on Confidence Judgements

Mahiko Konishi[1], Clemence Compain[1], Jerome Sackur[1] and Vincent de Gardelle[2]
[1]Département d'études cognitives, École normale supérieure, PSL Research University, France
[2]Centre d'Economie de la Sorbonne, Paris School of Economics, France

Humans have often trouble performing two tasks at the same time. Indeed, multitasking has consistently been shown to come with costs in behavioral, or Type 1, performance. However, the potential impact of multitasking on metacognition, or Type 2 performance, has received little attention in comparison. Does the capacity to judge our own performance change when we are involved in more than one task at once? We investigated this question using a visual dual-task paradigm: Participants were presented with a random-dot kinetogram and had to respond to the change in colour or of the movement of the dots, creating conditions of single- and dual-tasking. Furthermore, they gave judgements of confidence on the accuracy of their response. Comparing conditions of single- versus dual-tasking, we discuss our results in the light of the influence that multitasking has both on Type 1 and Type 2 performance as well as on participants' metacognitive bias.

Lateral Inhibition Between Evidence Accumulators Explains Magnitude Sensitivity in Perceptual Decision-Making

Angelo Pirrone and Sheng Li
School of Psychological and Cognitive Sciences, Peking University, China

Magnitude sensitive behavior has been observed in humans and monkeys. For example, humans are faster in judging which of two stimuli is brighter when presented with two equally high-brightness stimuli than when presented with two equally low-brightness stimuli—although the overall brightness of the stimuli is task-irrelevant, and the difference in evidence between the two stimuli in the high and low overall brightness conditions is constant and equal to zero. We show that magnitude sensitivity is driven by single-trial dynamics in a bottom-up fashion and not by top-down strategic adjustments that have been proposed. Furthermore, we test conflicting bottom-up accounts that have been proposed for this phenomenon, and we provide evidence for magnitude sensitivity arising as a consequence of lateral inhibition between evidence accumulators. Our results challenge the magnitude insensitive, optimal account of decision-making in which only difference in evidence is integrated.

Visual Temporal Representation Elicits Early Responses in Human Auditory Cortex

Maria Bianca Amadeo, Claudio Campus and Monica Gori
Unit for Visually Impaired People, Istituto italiano di tecnologia, Italy

Vision and audition interact within low-level cortical sites and at early latencies. An impact of visual inputs into auditory cortex has been observed in non-human primates, ferrets, rats and also in humans using functional magnetic resonance imaging, electrical cortical stimulation and transcranial magnetic stimulation techniques. However, previous studies failed to demonstrate a reliable early response of the human auditory cortex to unimodal visual stimuli. Here, we show that the construction of temporal metrics within the visual modality elicits an early activation of the human auditory cortex. A response occurs in fronto-central and temporal areas between 50 and 90 milliseconds after visual flashes during a temporal bisection task, mimicking many characteristics of the N1a component usually elicited by auditory stimuli. The same early activation does not appear during a spatial bisection task with identical visual stimuli. These findings suggest that early recruitment of the auditory brain may be necessary to build a temporal metric of events, whatever the sensory modality.

Temporal Visual Representation Elicits Early Auditory Responses in Normal Hearing but Not in Deaf Individuals

Monica Gori[1], Maria Bianca Amadeo[1], Chiara Valzolgher[2], Francesca Baruffaldi[3], Francesco Pavani[2] and Claudio Campus[1]
[1]U-VIP Unit for Visually Impaired People, Istituto Italiano di Tecnologia, Italy
[2]Center for Mind/Brain sciences (CIMeC), University of Trento, Italy
[3]Sezione Provinciale di Trento, Ente Nazionale Sordi ONLUS, Italy

The functional role of the interactions between vision and auditory cortices is not yet understood. We recorded event-related potentials (ERPs) and psychophysical responses in 12 hearing and 12 deaf participants while performing spatial and temporal visual bisection tasks. They observed three lights and judged the temporal or spatial relative position of the second one with respect to the other two. Visual flashes during temporal bisection elicited an ERP response in fronto-central and temporal areas in typical hearing and not in deaf subjects. This response appeared 50 to 90 milliseconds after the second flash mimicking the N1a ERP component usually elicited by auditory stimuli. Similar activations were missing for both groups during spatial bisection, involving identical visual stimuli. We demonstrate that in sighted but not in deaf individuals the auditory cortex has a pivotal role in visual temporal representation, suggesting that early auditory processing is necessary for high-resolution temporal relationship of events.

The Space Occupied by an Invisible Body: Peripersonal Space as a Coupling Prior

Massimiliano Di Luca[1], Jean-Paul Noel[2], Majed Samad[1], Andrew Doxon[1], Justin Clark[1] and Sean Keller[1]
[1]Research Department, Oculus, CA, USA
[2]Vanderbilt Brain Institute, Vanderbilt University, TN, USA

The integration of body-related sources of information within peripersonal space (the volume immediately surrounding the body) scaffolds body ownership. Here, we propose to account for this process using Bayesian inference, whereby objects near the body are expected to elicit bodily sensations because of an increased visuo-proprioceptive a-priori coupling probability. To test this idea, in a

highly realistic virtual reality simulation we showed a dot near the index finger under the table, asking participants to touch the locations of the dot and finger sequentially. If the reaching hand was not rendered, touches to the two targets were equally biased towards each other. If the hand was visible, only pointing to the finger was biased and vision was more precise. This pattern is consistent with a probabilistic visuo-proprioceptive mapping in peripersonal space, where the strength of coupling is modulated by environmental parameters including the visibility of the body.

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